MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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VOLUME XXIV.

Published by order of His Excellency the Governor General of India in Council.

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CHAPTER I.

GENERAL REMARKS.

§ 1.—*Introductory.*

FROM comparatively early times there has always been a strong desire to work the coal occurring in the Damudas of the Sátpura hills; and numerous efforts in this direction have been made, and small quantities of coal extracted, and practically tested with more or less favourable results. The only endeavour, however, that can be said to have met with any success, is the establishment of the colliery at Mohpani. It has long been doubtful whether the coal at this place might not at any time become exhausted or the supply cease on account of the unremunerative cost of obtaining it; and as the precarious nature of this supply became more evident, endeavours were made to find coal in sufficient quantities, and in accessible localities in other parts of the Sátpura region.

Experimental borings.

With this object in view, borings were undertaken in the alluvial ground to the north of the Mohpani field; in the neighbourhood of patches of Talchir rocks; in the Dudhi, Tawa, and Morun valleys; and in the neighbourhood of the known seams in the Betul district.

Attention turned to the Pench valley.

These localities were first tried, as being within reasonable distance of a railway (the Great Indian Peninsula Railway), but the experiments having failed to prove the presence of coal in sufficient quantity, and of a quality to make it worth while to put down experimental shafts, attention was turned to the seams in the south-eastern part of the basin, some of which had been noticed by Mr. J. G. Medlicott in 1857, others by Mr. W. T. Blanford in 1866, and several discovered since that time by Major Ashburner, one of which was worked to a small extent.

New survey.

During the two working seasons 1884 to 1886 I was sent to examine this part of the country. At the end of the recess season of 1885 at the request of the Government of the Central Provinces, I recommended sites for borings in order to test the most promising seams that I had up to that time visited; these in several cases corresponded with those recommended by Mr. Blanford in 1866. Nothing further has, however, been heard of these proposed trials, and it is doubtful whether unless the results were very favourable the working of the seams would prove remunerative on account of the difficulties of transport in any direction. Without a railway this attempt would be hopeless, but for the coal only a railway would not be remunerative, and it is thought at present that very little other traffic could be expected on this line.

§ 2.—*Physical Description.*

Area described.

The area described consists of portions of the Chhindwara and Betul districts situated between 22° 0′ and 22° 20′ north latitude and 77° 50′ and 79° 5′ east longitude.

Drainage.

The eastern portion, between the Motur range and the metamorphics to the south, as far west as the Kanhan river, is fairly level and cultivated, and is drained by the Pench, the Takea (a tributary of the Kanhan), and the Kanhan

rivers, all belonging to the Godavari basin. To the west of the Kanhan, the Tawa takes its rise and with its tributaries drains the whole of the country to the west into the Narbada. Near its head-waters the Tawa falls steeply from the level of the metamorphic plateau. The watershed between the Tawa and Kanhan is thus steep towards the west, and has a very gradual slope towards the east.

Cultivation.

The eastern portion of the area watered by the Pench river is well cultivated, as also some of the land to the west near Shahpur, but the remainder consists of jungle with a few small villages scattered about here and there, the inhabitants of which gain a scanty living by cultivating their small fields and by tending their meagre flocks.

Timber.

Over portions on the area teak, sal, salhe (*Boswellia*), pipal, &c., are to be found, but for the most part the trees are not of any great size. Bamboos of a fair size are common in portions of the area, especially on the slopes of the hills.

Inhabitants.

The inhabitants are mostly Gonds who, so far as my experience goes, are very averse to any unaccustomed labour or anything which necessitates their travelling beyond the limits of their daily experience.

Climate.

The climate is pleasant up to the month of April, but at times, especially before the setting in of the cold weather, jungle fever is very prevalent.

§ 3.—*Geological Table.*

The rocks of this region are as follows, the Gondwana system being quoted as given in the Manual, page 217:—

Alluvial deposits.
Deccan trap.
  Inter- and infra-trappean.
Upper Gondwana.
  Jabalpur group.
  Mahadeva series.
    Upper: Bagra group.
    Middle: Denwa group.
    Lower: Pachmarhi.

Lower Gondwana.
Damuda series.
Upper { Bijori group.
Motur group.
Lower: Barakar group.
Talchir group.

My work having been almost entirely in the Talchirs and Lower Damudas, I do not propose to consider in detail anything outside their limits, as the working out of the upper rocks requires a detailed study of ground that I have only very partially visited, and so far I see no reason for interfering in any way with what has already been done by previous observers of these rocks in this and other areas.

§ 4.—*Previous Observers and History of the Field.*

1827. CAPTAIN COULTHARD.

The earliest recorded notice of this field is by Captain Coulthard in a foot-note to his paper on the Trap of Sagar.[1] He, however, does not seem to have visited the locality where he mentions coal as occurring.

1831. LIEUTENANT FINNIS.

Lieutenant Finnis[2] describes an outcrop of coal in the Bhoora Nuddee near the hill of Jamgurh, and gives a section and map of the locality; from these it would appear that he referred to the outcrop at Sonada. Mr. Prinsep analysed the coal found by Lieutenant Finnis.[3]

1833. CAPTAIN OUSELY.

In 1833 specimens of coal were received by the Asiatic Society and analysed.[4] They were found by Captain J. R. Ousely in the "hills south of Fatehpur in the Hoshungabad district"; he traced the deposit for some distance. At the end of 1833[5] further specimens were received from Captain Ousely by the Asiatic Society.

1834. LIEUTENANT FINNIS.

The same coal is mentioned[6] in 1834 in Lieutenant Finnis' description of the geology of the country between Hoshungabad and Nagpur.

[1] Asiatick Researches, XVIII, pt. 1, p. 72.
[2] Gleanings in Science, No. 33, for September 1831, p. 293.
[3] *Ibid.* p 283.
[4] Jour. As. Soc. Bengal, II, 435.
[5] Jour. As. Soc. Bengal, II, 645.
[6] Jour. As. Soc. Bengal, III, 71.

MR. J. G. SPILSBURY.

In the same volume of the Journal of the Asiatic Society is a paper by Mr. J. G. Spilsbury on a geological section across the valley from Tendukheri to Bittoul,[1] in a note to which a reference is made to the same coal and the discovery attributed to Captain Ousely, who sent specimens in March 1827 to Mr. Maddock, Captain Coulthard, &c.

1835. CAPTAIN OUSELY discovers Mohpani coal.

On January 5th 1835[2] Captain Ousely discovered the coal now worked by the Nerbudda Coal and Iron Company, at Mohpani, in the bed of the Sitarewa river and also a bed at the junction of the Hard and Sakar rivers now known to be of Jabalpur age.

1838. Coal Committee.

In 1838, the Sonada and Mohpani coals are mentioned in the first report of the Coal Committee[3] under the heads of Towah river and Sakar river coals.

1838. Coal sent to Bombay.

In 1838, Major Ousely sent 206 bullock loads of coal to Bombay for trial, apparently from the Mohpani seam. The coal was tried in the engines of the *Indus* (a small Government steamer), and the results compared with those of Glasgow coal; the report by Captain H. B. Turner was very favourable, though the coal was said to be objectionable on account of the large amount of clinker.

1845. Final report of the Coal Committee.

In the second and third reports of the Coal Committee no further information is given, but in the final report in 1845,[4] the Mohpani coal is again referred to, and also the seam at the junction of the Hard and Sakar rivers, and seams at Mardanpore, Boragurh, and Sonadeh.

1847. Coal analysed by Professor Giraud.

In 1847, Professor Giraud[5] analysed some of the "Nerbudda coal" and reported unfavourably upon it on account of the small proportion of fixed carbon and the large proportion of ash. Trials of the same coal

[1] Jour. As. Soc. Bengal, III, 388.
[2] Jour. As. Soc. Bengal, IV, 648.
[3] Reports of a Committee for investigating the Coal and Mineral Resources of India.
[4] Sel. Rec., Bomb. Govt., XIV.
[5] Final Report of the Coal Committee, 1845.

at the same time in the steam factory of the Bombay dockyard gave results upon which the coal was reported to be not much inferior to the best Government coal.

1848. SIR R. HAMILTON sends coal to Bombay.

In 1848, Sir R. Hamilton,[1] the Resident at Indore, had a large quantity of coal raised at Sonadeh by Mr. Johnstone, which was forwarded to Bombay in charge of Captain Fenwick by water, and on its arrival trials were made with it on board the steam vessel *Medusa* by Lieutenant H. W. Grounds, who says in his report, "I would respectfully beg to represent that the general use of it in marine purposes will be found to give but little or no favourable result, as it is almost impossible to keep steam up, even with the throttle valve quarter open and this as proved in the *Medusa*, whose draught is generally very favourable." In consequence of this very unfavourable report the coal was again tested (in 1849) in the boiler of the factory engine at the Bombay dockyard, with the result that "the coal when sifted is in all respects quite equal to the best coal usually imported here for the use of the Government steamers."

1852. DR. JERDON and LIEUTENANT SANKEY.

In 1852, Dr. Jerdon and Lieutenant Sankey[2] visited the outcrop at Barkoi which was subsequently visited and more fully described by the Reverends R. Hunter and Stephen Hislop.[3]

1854. MR. JACOB.

In 1854 Mr. A. A. Jacob, Assistant Engineer and Geologist to the Bombay Baroda and Central India Railway Company, visited and reported on the coal at Sonadeh and Mohpani.[4]

1854. MR. CARTER'S Summary.

In January 1854[5] Mr. H. J. Carter published his Summary of the Geology of India (reprinted in 1857 with foot notes in Geological Papers on Western India).

[1] Sel. Rec., Bom Govt., XIV, and J. A. S. B., XVIII, 461 and 594.
[2] Quar. Jour. Geol. Soc., X, 55.
[3] Quar. Jour. Geol. Soc., XI, 556.
[4] Sel. Rec., Bomb. Govt., XIV, 136; Journ. Geol. Soc., Dublin, VI, 183.
[5] Journ. Bomb. Branch R. As. Soc., V, 179.

Rev. S. Hislop.

In 1854[1] also Rev. S. Hislop's paper on the Age of the coal strata in Western Bengal and Central India was published.

1855. Mr. J. G. Medlicott's report.

In 1885 Mr. J. G. Medlicott[2] wrote a brief report on the results of his examination of the Narbada valley with regard to the commercial value of the coal and iron deposits then known to exist in that district. He visited the seam at the junction of the Hard and Sakar rivers, and after a careful examination came to the conclusion that "the coal was commercially worthless and offered no reasonable prospect whatever of repaying the labour of digging down on the chance of improvement." Of the coal at Mohpani he seems to have formed a favourable opinion. He also visited the Shahpur outcrops, from which Mr. Johnstone extracted the coal which was sent to Bombay for trial. He considered that the hope of finding any beds of good coal in that part of the district was slight, and that the country to the east was more likely to reward future examination.

1855. Rev. S. Hislop.

In 1855 a paper[3] by Rev. S. Hislop was published, on the connection of the Umreth coal-beds with the plant beds of Nagpur, &c., in which he refers to the coal at Barkoi.

1856. Dr. Oldham.

In 1856 Dr. T. Oldham[4] read a paper before the Asiatic Society of Bengal on the Geology of Central India.

1857. Mr. Blackwell.

In 1857[5] Mr. J. H. Blackwell, Mineral Viewer for Bombay, reported on the mineral districts of the Nerbudda valley. He seems to have visited only the Mohpani outcrop, of which he formed a good opinion both as regards position and the quality of the coal, and the outcrop in the Sher river of Jabalpur age.

[1] Q. J. Geol. Soc., London, XI, 1,555.
[2] Sel. Rec. Govt. India, X, 12.
[3] Q. J. Geol Soc., London, V, 179.
[4] Jour. As. Soc. Bengal, XXV, 249
[5] Sel. Rec. Bomb. Govt., XLIV.

1860. Mr. J. G. Medlicott.

In 1860[1] Mr. J. G. Medlicott's report on 'the Geological Structure of the central portion of the Nerbudda district,' embracing the work of four seasons, was published. This memoir includes the whole of the area over which I have been working. At that time the Topographical Survey had not begun, and Mr. Medlicott was obliged to draw his own map, which was published with his memoir on the scale of 1 inch = 4 miles.

1860-61. Company started to work coal at Mohpani.

In 1860-61 a company was started, through the instrumentality of Mr. Blackwell, to work the coal at Mohpani and iron at Tendukhera.[2]

Central Provinces Administration Reports.

In the Administration Reports of the Central Provinces there are several references made to the Satpura coal basin. In that of 1861-62[3] Mohpani is stated to be worked by a European company and the coal at Umreth by Mr. Stanborough. In 1862-63[4] the Officiating Chief Commissioner visited the Barkoi mines in the company of Mr. Hislop. In 1864-65[5] negotiations were being entered upon for working the Barkoi and Shahpur seams, and Major Ashburner's discoveries of coal are referred to. In 1866-67[6] Major Ashburner was deputed on special duty to explore for coal, and a company had applied for a mining license over a portion of the Chhindwara field.

1886. Mr. Blanford's report.

In 1866 Mr. Blanford reported on that portion of the region known as the Pench river coal-field. The report was published in 1882.[7] He visited the 11 outcrops of coal seams which had been discovered up to the time of his visit, at the east end of the area, chiefly through the exertions of Major Ashburner, the Deputy Commissioner of the Chhindwara district. The report speaks very favourably of several of the outcrops, and recommends further exploration by means of borings, which however have not up to the present time been carried out.

[1] Mem. Geol. Surv. India, II. pt. 2.
[2] Admin. Rep., N.-W. Provinces, 1860-61.
[3], [4], [5], and [6] Admin. Rep. of C. Provinces.
[7] Rec. Geol. Surv. India, XV. 2, 21.

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MAP.

1867.
MR. A. SOPWITH.

Early in 1867[1] the coal districts of Narsinghpur, Hoshungabad, Betul, and Chhindwara were examined under directions from the Great Indian Peninsula Railway Company by Mr. Arthur Sopwith, and a license to the company to mine at Lokartalai was sanctioned by the Government of India, but active operations were retarded owing to delay in opening up the railway.

1867.
DR. OLDHAM.

In 1867[2] Dr. T. Oldham gave a summary of the information up to date.

1868.
MR. BLANFORD.

In 1868[3] Mr. Blanford published a paper on the coal seams of the Tawa valley in which he gave an unfavourable opinion of the chances of working the coal profitably.

1870-72.
MR. H. B. MEDLICOTT.

In 1870[4] Mr. H. B. Medlicott published a short paper on the Mohpani coal-field. In 1871[5] he published a Note on the Nerbudda coal basin, dealing chiefly with the prospects of obtaining coal along the northern boundary of the basin, the progress at Mohpani, and the outcrops at Lokartalai, which he ascribed to rocks younger than the Barakar group.

In Mr. Medlicott's Notes[6] on the Satpura coal basin, published in 1872, we have a sketch of the geology of the whole of the Satpura area. Again in 1872[7] Mr. Medlicott published a further Note[7] on Exploration for Coal in the northern region of the Satpura basin, in which he gives a sketch of the progress at Mohpani, and recommended borings at Budi in the Dudhi valley and South of Kesla in the Tawa valley, in order to test the presence of coal at a workable depth below the Upper Damuda rocks between the known outcrops of the Lower Damudas at the north and south of the basin. At the same time he recommended borings in the alluvial deposits to the north at Gadarwara and Bunkheri in order to determine whether they are

[1] Admin. Rep. of C. Provinces.
[2] Memo. on the Coal Resources of India, Sel. Rec. Govt. I., LXIV.
[3] Rec. Geol. Surv. India, I. 1, 8.
[4] Rec. Geol. Surv. India, III. 3, 64.
[5] Rec. Geol. Surv. India, IV, 3, 69.
[6] Mem. Geol. Surv. India, X. 2, 133.
[7] Rec. Geol. Surv. India, V. 4, 109.

underlaid by metamorphic rocks or by formations belonging to the coal series, in which case there would be a possibility of workable coal being found.

1872-73. Shahpur coal tested.

In 1872[1] a few tons of coal were forwarded from Mardanpur and Dolari for trial by the Great Indian Peninsula Railway Company, the report of whose engineers was on the whole favourable, but a larger quantity (300 tons) was asked for and supplied. The experiments were commenced in the hot weather and temporarily abandoned. In 1873-74[2] the experiments with the Shahpur coal were continued and are stated to have justified a favourable opinion of the coal for locomotive purposes; the report states that the coal was free from white ash, but that it clinkered badly, necessitating the frequent cleaning of the fire-bars.

The subsequent Administration Reports of the Central Provinces mention the 16 borings which were put down in various parts of the basin to search for coal but without success, and several inspections of the coal mines at Mohpani.

1875. Progress of borings.

In 1875[3] Mr. Medlicott in his paper on the Shahpur Coal-field mentions the unsuccessful result of the borings at Gadarwara station and Sukakheri, which were carried down to 251 feet and 491 feet respectively all in alluvial deposits.

He mentions, as regards the borings in the Dudhi valley, that borings were commenced at Manegaon and Khapa, which reached respectively depths of 419 feet and 472 feet, at the close of the season 1874-75 in coloured clays and sandstones. Borings were also commenced at the Suktawa river and at Kesla during this season, and had reached depths of 241 feet and 302·5 feet respectively at the end of the season. At the same time he recommended borings along the north boundary, 7 miles west of Mohpani, one on each of the roads to Pachmarhi, and one at Lokartalai, and three borings in the Shahpur field. The extension of the Satpura basin to the west of Lokartalai is con-

[1] C. P. Admn. Rep., 1872-73.
[2] ,, ,, ,, 1873-74.
[3] Rec. Geol. Surv. India, VIII, 3, 65.

sidered in the same paper in which also the Shahpur field is described and a map given.

1878.
Progress of borings.

In 1878[1] in his annual Administration Report for 1877 Mr. Medlicott gives the progress which had been made with the borings since his last paper. The Khapa boring had been carried down to a depth of 720 feet without change of formation. The three borings at Tundni (10 miles west of Mohpani) were carried down only to 328 feet, 172 feet, and 243 feet, and stopped on account of the difficulties encountered. At Lokartalai a boring was carried down to a depth of 254 feet, to the deep of the carbonaceous outcrops there. This boring proved that the coaly bands did not improve, and a subsequent discovery of fossils by Mr. Hughes showed these beds not to belong to the Lower Gondwanas. Two other borings put down 60 yards apart at the lowest point of the section, to try the underlying strata, were stopped at 84 feet and 88 feet by induration in the sandstone. As regards the two borings on the Pachmarhi roads, the one on the road from Pipria station within 50 yards of a Talchir outcrop was sunk to a depth of 285 feet in Upper Gondwana rocks, thus proving the impracticability of endeavouring to work coal here even if the junction is not faulted; the other one on the Anjan river was at the time of writing down to 186 feet in mottled sandy clay of the Bagra group, this boring was also close to a patch of Talchirs.

1878.
DR. FEISTMANTEL.

In 1878[2] Dr. Feistmantel made a traverse across the Satpura basin, with the object of obtaining fossils from that region. He points out from palæontological evidence that the Mohpani coal seams belong to the same horizon as the coal beds of Karharbari. He also found fossils near Barikondam in the Bijori horizon of Mr. Medlicott, which correspond with those of the Raniganj group of Bengal. He was also able by means of the plant remains to identify the same beds to the west, about 5 miles from Rorighat. Some of the coal beds (Kotmi, Temni, and Dolari)

[1] Rec. Geol. Surv. India, XI. 1, 1.
[2] Pal. Ind. Ser. XII. 1, and Rec. Geol. Surv. India, XII. 1, 74.

in the Shahpur field he assigned to the Karharbari beds, the rest were doubtful on account of the absence of fossil evidence, but there was some possibility of their being of Barakar age.

1879. Progress of borings.

In 1879[1] in a note on Mohpani coal-field Mr. Medlicott gave a sketch of the progress made at Mohpani and also of the concluding operations in search of coal. The Anjan borings is reported to have been carried down to a depth of 350 feet without piercing the red rocks of the Mahadeva series.

A boring was put down at Benar, at the bottom of an old shaft, 118 feet deep and carried to a total depth of 426 feet; the last 247 feet being in sandstone resembling that of the Barakars, and containing carbonaceous shale and even fragments of coal, without any coal seam being struck, though in adjoining parts of this field the coal lies within 150 feet of the top of the coal-measure rocks.

Manual of the Geology of India.

In the Manual of the Geology of India, such information as was available on the subject is given up to date; but in this part of the Manual questions of economic geology were not taken up.

1882. Progress of explorations.

In his annual Administration Report for 1882[2] Mr. Medlicott placed on record the latest operations in this basin, *viz.*, the three borings which were put down in the Shahpur field. He writes :—

"Two of them were made to a depth of 400 feet and the third to 539 feet. They all passed through several coaly seams, with some thin bands of coal; but none were of sufficient promise to recommend the sinking of a trial shaft. I believe that all the coal-bearing measures were passed through in each boring, but the seams are even poorer than at their outcrops. The coal prospects in the Satpura basin are thus reduced (besides the Mohpani mines) to the Pench valley field, of which Mr. Blanford gave a very encouraging report in 1866 (Records Vol. XV, part 2, 1882). This field has naturally been left to the last on account of its comparative inaccessibility; but the engineering difficulties to be overcome are nothing like so great as those on the new Indore and Bhopal State Railways, and a line from Itarsi up the Tawa valley to the Pench would be in every respect the most favourable for crossing the Satpura range between the Narbada valley and Nagpur. Such a line would pass along the Shahpur coal-field, and might lead to a further exploration of those measures."

[1] Rec. Geol. Surv. India, XII. 2, 95.

[2] *Ibid*, XVI. 1, 1.

CHAPTER II.

IDENTIFICATION AND DISTRIBUTION OF ROCKS.

§ 5.—*Metamorphics.*

Exposed along the southern boundary.

The metamorphic rocks are exposed all along the southern boundary of the area; the junction with the sedimentary rocks is, however, covered at the eastern end by trap, though only as far as a short distance west of Dala village (E. Lon. 78° 54′), beyond which the boundary is free from trap to the extreme west, where it is again covered.

Inliers north of the boundary.

There are also some remarkable inliers of metamorphic rocks separated from the main mass by the Talchirs; they are in no case at any great distance from the boundary, and in most cases they are in the neighbourhood of faults which lie to the north of them and have an upthrow to the south. This is well seen in the inliers at Chuttoa (E. Lon. 78° 39′), Bhaweye (E. Lon. 78° 34′), Chordongri (E. Lon. 78° 8′), and near Binsandhana (E. Lon. 78° 27′); there are also several small inliers in the deep valleys near the boundary north of Niramba-Jameye villages (E. Lon. 78° 27′), though here the connection with the faults is perhaps not so evident, as they are situated at a much greater distance from the line of faulting. The spur of metamorphics running out to the east by Diheri and Tutama (E. Lon. 78° 23′) may probably be traced to the same cause. This line of faulting has thrown up the rocks to the south of it relatively to those to the north. The tendency of denudation has been to keep the surface of the ground level so far as allowed by the inequalities in resisting power of the various rocks to the eroding forces. The surface of metamorphics on which the Talchirs were deposited must have been very uneven, and inliers would have eventually appeared without the existence of the faults, though the presence of the faults, by bringing the bottom rock to a relatively higher level, has hastened their appearance.

Petrology.

The metamorphics consist of the usual gneisses and schists, and at one point between Oomerghor (E. Lon. 78° 38′) and Dhadra (E. Lon. 78° 40′) I found schists containing numerous garnets.

§ 6.—*Talchirs.*

Extent of Talchirs.

Except at the extreme eastern end, by Sirgora (E. Lon. 78° 57′), and as far as the Pench river, to the west of which they first put in an appearance, the Talchirs are represented along the whole of the area from near Dala village (E. Lon. 77° 44′) on the Pench river in Chhindwara, to a point south of Parsuda near the Moran river in Betul, though for a short distance between Khursadeye and Mooeari they are covered by trap.

Talchir-metamorphic boundary.

As regards the Talchir-metamorphic boundary, it is, with the exception of that portion belonging to the small area of Talchirs exposed south of Harai (E. Lon. 78° 51′), concealed at the eastern end by trap. In this little patch there is a very good exposure of the Talchirs, in the Kopadoh stream running past Khursadeye (E. Lon. 78° 50′), from the point where the stream leaves the Barakars to its junction with the Puthreye river and for a short distance up the Puthreye itself. The Talchirs here consist of the usual finely jointed shales, containing numerous transported boulders varying much in size, from that of a hazel nut to 2 or 3 feet in diameter. To the east of the junction of the Kapadoh and Puthreye streams the Talchirs are exposed for a short distance in the latter, and then a trap dyke passes across beyond which the metamorphics are seen. The Talchirs are again exposed in the small streams to the north of the Puthreye. The rocks here do not present the appearance of having undergone disturbance, though owing to the unstratified and miscellaneous character of the boulder bed it is impossible to tell what the dip is.

This is probably near the local eastern limit of the Talchir basin, for the exposure is here very narrow, and these rocks do not appear to the east at any of the places where the trap has been denuded and the metamorphics exposed.

Original eastern boundary.

To the west of this outcrop the Talchirs are covered by the trap, beyond which again they extend uninterruptedly as far as the extreme west of the Shahpur field. The actual boundary is not well exposed, but where seen in the streams passing across it near Kharee (E. Lon. 78° 43′), Optee (E. Lon. 78° 41′), Omerghor (E. Lon. 78° 38′), and Kamkhera (E. Lon. 78° 36′), it is quite normal and shows no signs of disturbance; the dip of the Talchirs in the immediate neighbourhood of the boundary is only 5° to 10°.

Continuation to west.

Beyond Mirka Dhana (E. Lon. 78° 34′) the boundary becomes much indented, following the line of the hills to a great extent, but also running into the low ground, as in the Tawa near Mirda Khera (E. Lon. 78° 33′). Where the boundary passes across the two streams known as the Ghogra and Kuchar Nalas (E. Lon. 78° 22′) it is quite normal, and the dip of the Talchirs is slight, to north-10°-west; beyond this the boundary is seen again at intervals to Bisighat (E. Lon. 78° 19′), still following the line of the base of the hills. Just beyond Bisighat it takes a sharp turn and runs back again to the east, a spur of the metamorphics running as far as a point to the south of the village of Bankatawa (E. Lon. 78° 25′). Along this portion the boundary is very irregular owing to the irregular floor on which the Talchirs were deposited. The Ghogra river, just before it enters the metamorphics, runs along the boundary, and for some distance the right bank and the lower 10 feet of the left bank are of metamorphics, while the Talchir boulder shales rest on the old denuded surface of the metamorphics on the left bank. The dip of the Talchirs just here is to the south at 10°, while further to the east it is only 6°. After turning west again, the boundary follows for some distance

The Ghogra section.

the line of the base of the hills, and where the Ghogra crosses it, just by Karanji (E. Lon. 78° 21′), the Talchirs lie up against the edge of the metamorphics, the plane of contact sloping down at an angle of 40° to the north and the Talchirs dipping steeply in the same direction; again by Lonia (E. Lon. 78° 17′), where the Tawa river runs just north of the boundary, there is a quartz vein just inside the boundary, and the junction is more abrupt than in other parts of the line. This section has already been described by Mr. J. G. Medlicott at page 240 of the 2nd volume of the Memoirs. Beyond this, the boundary is not well exposed again till it reaches the Deriakho river where it is perfectly natural, though there are several veins of quartz in the vicinity.

Talchir outliers.

There is a small outlier of Talchirs to the south of the boundary near this point and five other smaller ones close by, only three of which are large enough to represent on the small scale map; the dips are all low. The boundary is again seen in the stream that runs into the Deriakho just below Chargaon (E. Lon. 78° 4′), beyond this it sweeps round to the north and is well exposed in several streams. In the Phopas river where it leaves the metamorphics, the Talchirs are well seen resting unconformably on the old denuded surface.

At the point where the Deriakho river passes for the sixth and last time from the metamorphics to the Talchirs, just before it joins the Tawa and just below its junction with the stream from Kaniwara, the Talchirs are seen much indurated with quartz in the bed of the river, and a short distance below the boundary there are two quartz veins, beyond which the Talchirs assume their normal appearance with a dip to the north of 10°. In the Deriakho river just above the boundary there is another small outlying patch of Talchirs with a dip of 20° to north-west. It is impossible, therefore, with all these outliers of Talchirs close to the boundary, that it can be a faulted one, especially when we take into consideration the otherwise natural condition of the junction.

Boundary not faulted.

Further to the west, the boundary is not particularly well exposed, but so far as can be seen, it presents no peculiar features as far as the Machna river, where it runs into the continuation of the Machna fault, accompanied by quartz breccia, which can be traced into the metamorphics for some distance beyond the limit of the Talchirs; it then follows this fault, the Talchirs being much disturbed and hardened by the infiltration of silica wherever they are seen in the immediate neighbourhood of the fault. By Amdhana west of Shahpur, the boundary leaves the fault and turning north follows the line of the base of the hills till it is covered at the extreme west near Dardhari by the trap.

Machna fault.

The only places along the whole of this line where there is any direct evidence of faulting are, in the section near Lonia, east of Matiardeo hill, and near Karanji where there is perhaps a continuation of the same fault, which may, however, be accounted for by slipping on a steep surface as a merely local phenomenon; besides this we have the fact that there are numerous inliers of metamorphics and outliers of Talchirs along the boundary which together with the irregular character of the boundary in parts, entirely shuts out the possibility of the boundary being to any great extent a faulted one, and suggests that the floor of deposition must have been very irregular, and along a great part of the line sloped away gradually towards the north from the boundary.

Boundary one of deposition.

The fault running past Lamti (E. Lon. 77° 56′) has of course nothing to do with the question of a great fault along the boundary, and has merely come to form a portion of it by throwing the Talchirs down to the south and thus protecting them from the effects of denudation.

Mr. H. B. Medlicott in his reports[1] on this ground has pointed to the probabilities of this southern boundary being one of original deposition, modified by a subsequent gentle rise of the ground to the

[1] Mem., Geol. Surv. India, X., 176, & Rec. VIII, 3, 76.

south. There is no evidence to show that the Talchirs ever extended far to the south of their present limit, and no traces of them have been found at any distance in that direction, though, taking into consideration the fact, that there has been a considerable rise to the south of the line of faulting inside the field, there is a possibility that they did so extend and have been subsequently denuded away.

Petrology.

The Talchirs consist of boulder beds to a very large extent, the shales almost invariably containing at least a few boulders and being often crowded with them, and the sandstones also frequently to a high point contain some boulders. The boulders are generally of gneiss and schist which might have been derived from the metamorphics in the vicinity, but in many cases there are also boulders of a much more variable character than anything exposed near, and there are occasionally, as near Pandra and Chordongri (E. Lon. 78° 7′), boulders of sandstone resembling some of the Vindhyan sandstones, which must have come from a distance; and as there is nothing particularly distinctive about the metamorphic rocks, the whole may have travelled from a distance.

The sandstones and shales have the greenish tinge peculiar to the Talchirs, and, except for the greater frequency of boulders, they resemble the same rocks as described in other fields.

The dip is as a rule northerly to north-westerly at low angles, not unusually exceeding 10°, though in places it is as much as 30°, and towards the south or east.

Thickness of the Talchirs.

Mr. H. B. Medlicott has estimated[1] the possible thickness of the Talchirs in a portion of the Shahpur field as over 2,000 feet of accumulated time-thickness.[2] This appears to be the portion of the whole area where they attain their greatest thickness.

To the west they continue to have a considerable thickness almost

[1] Rec., Geol. Surv. India, VIII, 80.
[2] Mem., Geol. Surv. India, X, p. 140, note.

up to the limit of the field; and in the hills to the west of Mura (E. Lon. 77° 49′), the actual thickness seen in section is nearly 1,000 feet. To the east, they are not so thick, though owing to the prevalence of trap dykes and the rolling of the beds, it is impossible to arrive at any certain estimate of the thickness. At the point where the Barakars of the Tawa field run down south almost to the metamorphic boundary, the actual thickness seen is very small; there are, however, no good exposures of the Talchirs at this point; but, from what can be seen, the dip is not high, and the disturbance at a short distance to the north does not seem to have affected the rocks here To the east of the Barakars here the Talchirs run up towards the north and the general direction of the dip is northerly, which is suggestive of a considerable thickness of Talchirs having been unconformably covered by the Barakars, which must have extended at one time as far as the present Talchir-metamorphic boundary.

Further east, the thickness does not probably exceed 500 feet, and at the extreme eastern end of the basin the Talchirs have almost died out, though here again this appearance may be to some extent due to overlap by the Barakars.

Across the Talchirs from Damoöa (E. Lon. 78° 30′), where they are superficially least disturbed by dykes the dip is very irregular.

Talchirs at high levels.

In several localities, as west of Mura (E. Lon. 77° 48′) near the Tamia river, running into the Tawa near Chomow, and in the extension of Talchirs among the metamorphics near Bhaldeye (E. Lon. 78° 20′), the Talchir boulder beds are found at a very high level, several hundred feet above the general level of the Talchirs in the plain. This is due to a great extent to the rising of the ground to the south, but where they occur in these positions, at a distance from the boundary (as near the Tamia), the unevenness of the floor of deposition has probably assisted in bringing them there, for if a deposit is being formed in water sufficiently still to allow of the fine particles of the Talchir shales settling down to the bottom, the material will be pretty evenly

distributed over the whole area and tend to form a covering representing to some extent the original form of the ground; only in those portions where the surface is too steep to allow of the material resting, will it more or less gradually subside giving rise to a disturbed condition of the strata near those points.

Sections.

The three diagramatic sketch sections (on the small map) show some of these features. In order to exaggerate the surface profile, and give an idea of the hilly nature of the country which is not always well shown on the map, the vertical scale is twice the horizontal scale.

§ 7.—*The Barakars.*

The Barakars in this basin are separated into several small areas partly by the overlying trap and partly by faulting. Commencing at the east we have:—

§ 8.—*The Sirgora Field.*

Area of small extent.

This is an area of but small extent, being only 1·1 square miles. The name adopted is that of the small village (E. Lon. 78°57′) near which the coal occurs. This area is entirely surrounded by trap which forms a part of the large flow extending to the east. The south boundary of the Barakars is covered by trap, but in the north-west corner there are some ferruginous shales and red clays exposed belonging to beds higher in the series. Below the trap of the hill to the east of Sirgora, there is a conglomeratic sandstone containing pebbles of red jasper and white quartzite, and resembling a rock in much the same position further to the east which is probably of infra or inter-trappean age.

Coal found in a well.

I[1].—The coal occurs in the neighbourhood of the village of Sirgora. It was found in a well sunk some years ago, at a depth of 28 feet, and it exceeds 4 feet 9 inches in thickness. I was unable to see this seam, as at the time of my visit the wells in this village were full of water; and as this locality had

[1] The roman numerals incorporated in the text refer to the list of coal localities.

been examined by Mr. Blanford in 1866, it was not advisable to have the well cleared out, for unless further excavations were made nothing new could have been learned. Mr. Blanford writes[1] :—

Exploration.

"The most eastwardly locality in which coal has yet been discovered is close to the village of Sirgori, and nearly a mile north of the Pench river. The coal was found in a well sunk, twelve years ago, by the malguzar or patel of the village; and this circumstance coming accidentally to the knowledge of Major Ashburner, led to the discovery not only of this seam but of all the others between Sirgori and Barkoi. Major Ashburner sank a shaft by the side of the well, and at the depth of 28 feet came upon the coal. All the beds cut through were of sandstone, coarse or fine; and the roof of the coal consists of coarse sandstone, obliquely laminated. After cutting into the coal more than 3 feet, water came in rather rapidly, and the shaft was stopped. With some little difficulty from the influx of water, I succeeded in digging into the coal further, until I had reached 4 feet 9 inches from the top of the seam. How much thicker it may be I cannot say. The whole is of good quality, perfectly uniform, without shale partings."

Coal in other wells.

In addition to this well, which is situated on the right bank of the Jobe stream, south-27°-east from the north-eastern portion of the village and east-5°-south from the south-western portion, I was shown three other wells in which coal is said to occur, one immediately to the south of the north-eastern portion of the village near the position Mr. Blanford recommended as a boring site; here 4 to 5 feet of coal is said to have been found in digging the well, at a depth of about 12 feet; this is only a few yards north of the trap beneath which the outcrop of the coal must be situated. The dip in the stream close by is north-west at 10°.

To east-32°-north from the larger or north-eastern portion of the village, on the bank of the Jobe stream, is a well which was dug about 1880, in which coal was found, but I was unable to obtain any information as to its depth beyond the fact that the usual depth of water in the well was 20 feet.

The third well is to the west of the north-east portion of the village, close to a small hillock, the coal is here said to be at a depth of about 15 feet.

[1] Rec. Geol. Surv. India, XV, 2, 124.

This gives an area of a little over one-eighth of a square mile over which coal is known to exist at a short depth below the surface, while at one point its thickness is known to exceed 4 feet 9 inches.

Besides this seam of coal there is an outcrop of carbonaceous shale in the stream to the east of the village below a white sandstone, which was being quarried at the time of my visit for building purposes.

Outcrop of another seam.

II. There is also the outcrop of a second seam of coal about half a mile west-north-west from the village further up the same stream. The section here seen in the stream in descending order is:—

	ft.	in.
Mottled sandstone	2	0
Mottled grey carbonaceous shales with coaly layers . . .	1	8
Mottled red shales with plant impressions	0	4
Grey clayey carbonaceous shale with thin bands of coaly matter	1	6
Coal: total thickness not seen, the bottom being covered by water, but Major Ashburner gave it as	3	0

Major Ashburner sank a shallow pit through this coal, north of the stream, and found it to be 3 feet in thickness. The dip is very slight and to the north, this is a distinct seam from the one found in the wells and is above it.

Hirunbhutta: A short way above the village of Hirunbhutta, on the right bank of the Mandla stream, and just below the point where the trap comes in, there is a 10-foot bed of carbonaceous shale dipping at two or three degrees to north-10°-west; there are 2 inches of coaly matter in this shale. The shale is overlaid by a white compact, rather flaggy, fine-grained sandstone which very closely resembles the sandstone above the carbonaceous shale in the stream to the east of the village of Sirgora. Taking into consideration the fact that the general dip in this field is north to north-west and seldom exceeds 10°, it is not unlikely that these are two outcrops of the same bed of carbonaceous shale. This shale was discovered by Major Ashburner subsequently to Mr. Blanford's visit in 1866.

If these two outcrops belong to the same bed of shale, it is not unlikely that the coal found at Sirgora will also be found beneath, as this seems to be a fairly constant seam; to test this it would be advisable to put down a boring here also.

Sirgora coal probably extends under this shale.

Mr. Arthur Sopwith also visited the Sirgora seam in 1867 when he reported on this area.

This Sirgora seam if explored would probably not be found to extend more than about one and a half miles to the north in a direct line, *i.e.*, as far as the run of the Pench fault, to which it owes its position; the fault, which will be more fully described in the next section, having thrown the Barakars and Moturs down at this point.

As regards an extension of the seam to the eastwards for any considerable distance along the strike, the chances are very small, as Sirgora is nearly at the eastern limit of the basin; for near Thesgora, 3 miles to the east-north-east, an inlier of metamorphics is exposed surrounded by the trap and the infra-trappean conglomerates, without any intervening Gondwana rocks. To the south the coal, though not seen, must either outcrop just north of the trap boundary or at a short distance under the trap. To the west it probably extends as far as the fault.

Seam not of any large extent.

§ 9.—*The Barkoi Field.*

The Barakars in this area cover 7·4 square miles. The name is that of a village (Burkooee of small scale map, E. Lon. .78°46′) near which an important seam of coal is exposed. To the south the field is cut off at the eastern end by the Pench fault, while further towards the west it passes under an outlying plateau of the basaltic formation. At the western end the Moturs, which form a watershed between the basins of the Kanhan and Pench rivers, cover the Barakars and extend along the northern boundary towards the east, till themselves covered by an extension of the main mass of trap. The field extends from

Area covered by Barakars.

north of the village of Chinda (Sinda, on the small map) to some distance beyond the village of Barkoi, a length of over 10 miles.

Pench fault.

The fault mentioned as forming the south boundary of this field towards the east is the same as mentioned by Mr. Blanford as having faulted the red clays and white sandstones of the Moturs against the coal-measure beds. In the Pench river the Barakars are seen in almost immediate contact with the red clays, and the coal is in actual contact with them in the banks of the Pathajhora stream just before it joins the Pench. Again going up the Dighawani stream we find the red clays for some distance and then just on the line of the fault at a small waterfall, typical Barakar sandstones come in. In the Nowreekhajooa Nala just above the crossing of the road between Rawanwara and Hurreye, sandstone of the usual Barakar type is exposed dipping to north-east at 10°, a little lower down the stream the same sandstone is seen dipping east-20°-north at 10°. Just opposite the village of Harai (Hurreye) the bed of the stream is in trap, to the south of which the mottled clays are exposed, but the dip is obscure. In the Dongur-Parasia Ghogra Nala the fault is again concealed by a trap dyke, on the north side of which there are Barakars, and on the south the red clays of the Moturs. Up the Amarwara Nala (the stream which flows past Bhandaria) there is a great deal of sandstone much indurated by infiltration of silica, this extends for some distance up the stream; just below the Bhandaria Ghogra Nala the trap of the hills to the south extends into the river bed, close by which Barakar sandstone is seen dipping to the west at 20°; at the next turn red clays and white sandstones of the Motur type are exposed dipping to south at 42°, and a short distance further up (just opposite the Ghogra Nala) the red clays are again seen beneath the trap. Beyond this point the fault either dies out or takes a turn to the south under the trap as it could not be traced any further.

This is a remarkably clear case of faulting, for not only can the actual fault be seen in several cases, but we have a long stretch

of the distinct upper rocks in immediate contact with the Barakars, and to the south of them, where they could not occur except by means of faulting. This is the only important fault with the downthrow to the south along the south of the basin, with the exception of the one at the west (the Machna fault), the other faults all having their downthrow to the north.

The amount of the throw in this case is not very considerable, as in the Setia (Saindra of large map) Jobe Nala and to the west the Motur clays are close above the coal in natural sequence, and at Harai coal-shale is found near the surface under the Moturs. There are several outcrops of coal in this field.

Chinda Dighawáni outcrop.

III. The Chinda Dighawani outcrop. This outcrop occurs in the bed of the Pench river between the two above mentioned villages.

Mr. Blanford who visited this locality in 1866 writes[1]:—

"The spot is just north of the ford in the Pench, on the road between the villages of Chinda and Dighawáni. About half a mile to the south, trap comes in, both in the river bed and on its banks; to the south of the trap, near the village of Dala, metamorphic rocks occur. North of the trap, for a considerable distance no rocks are seen; at the ford the deep red clays and white sands, to which I have already referred, and which I believe to belong to a higher series of beds than those associated with the coal, are seen dipping about 20°, to south-10°-west. They are faulted against the Damudas, or coal-measure beds close by, and, about 100 yards north of the fault, coal appears on the east or left bank of the river.

"At this spot Major Ashburner has made a small cut into the coal to ascertain its thickness; this cut exposes the following section:—

	Ft. In.	Ft. In.
Shale, decomposed, about		3 0
Coal ditto	1 0	
Shale	1 3	
Coal rather shaly in places but generally of fair quality	7 0	
Shale, in parts very carbonaceous and containing layers of good coal	2 0	
Coal of good quality	4 3	15 6

of which 12 feet 3 inches consists of coal.

[1] Rec. Geol. Surv. India, XV. 2, 127.

Immediately to the north, a trap dyke running east and west, and about 30 yards broad, crosses the seam. This great mass of igneous rock has tilted up the seam slightly to the north, but does not appear to have much affected the coal. The seam re-appears just north of the dyke, dipping north, at first at an angle of about 10°, but immediately beyond, at a much lower dip, varying from about 3° to 5°. For about 150 yards from the dyke, the outcrop of the coal seam occupies the bed of the river; then massive sandstone comes in, apparently brought up by a small fault, striking nearly east and west, with an upthrow of about 20 feet to the north. The sandstones dip to north-10°-east at about 5°, and, upon them, about 30 yards further, the coal seam re-appears; that is to say, coal of great thickness comes in, and it has every appearance of being the same seam. If not, two very thick seams must here occur, one above the other, and separated by only a few feet. The coal seam continues to crop out in the bed of the river for a short distance, when it is covered by the overlying trap, which forms both the bed of the stream and the hills on its banks. This trap continues for a considerable distance up the river."

Coal outcrops at other spots.

The coal is also seen in several spots to the west. In the Jobe stream south of Dighawáni, I found fragments of coal imbedded in the alluvial banks of the stream, but I could find no further indications of coal at this spot. In the Pathajhora stream to the east of Dighawáni, just above the crossing between Dighawáni and Setia (Saindra), clayey shales with carbonaceous layers occur dipping to north-20°-east at 10°; following down the stream some way below this there is a thin band of coal dipping north at 8° with shale above and below it, the shale dipping at 20° to north. The shale and sandstone can be traced for some distance down the stream, till just above its junction with the Pench, at which point the red clays of the Moturs are faulted right against the coal and shale.

In a small watercourse, north of this stream, the shale and coal are again seen extending nearly down to the Pench.

In the next watercourse to the north the coal occurs in close proximity to the trap dyke mentioned by Mr. Blanford and to the south of it.

In the next watercourse to the north known locally as the Ghogra Nala and distinguished by a Pipal tree which grows close to it on the north side (the only one of these small watercourses north of

Pathajhora marked on the map), there is another exposure mentioned by Mr. Blanford. Here a shallow pit had been sunk by Major Ashburner on the coal; I had this cleared out and found 8 feet of coal, but owing to the rapid influx of water I was unable to continue the hole any deeper.

The dip of the coal is moderate and the coal thick, and I believe that except for the difficulty which would probably be experienced from the water, the chances of a good outturn of coal are as favourable here as anywhere. In the Setia Jobe river to the north-east of the coal outcrop, the red clays of the upper rocks crop out; these must extend under the trap and have afforded protection to the coal at the time of the trap outflow.

The water difficulty above referred to as reducing the probable value of this seam is declared by the numerous springs which flow out from the coal where it is exposed in the river banks. When I visited the locality it was the end of December, when the rains had been over for nearly three months, so that the flow of water must be a pretty constant feature here, and unless some means could be found of reducing it, it would necessitate costly machinery for pumping.

Large amount of water.

IV.—In the Seemkole stream west of Rawanwara (locally known as Ghogra Nala) some coal is exposed. Mr. Blanford gives the section as seen by him, and I have reproduced it side by side with another section seen 50 feet to the south-west of his section, in order to show the extremely variable character of the rocks horizontally; the dip of the beds being the same in both cases (only 7° N.), so that at the short distance—50 feet or 29 feet in the direction of the dip—the lower beds of the first section should recur in the second, if not disturbed. The clays and sandstones of the second section have the mottled appearance of the Motur beds; there is also a small fault below this in the stream where the coal is thrown down 2 feet.

Seemkole outcrop.

1.

Mr. Blanford's section.

	Ft.	In.	Ft.	In.
Shaly sandstone			4	0
Fine compact sandstone			2	6
Coal	1	0		
Sandstone, shaly in part	1	3		
Carbonaceous shale and coal	0	4		
Sandstone with streaks of coal	0	7		
Carbonaceous shale and coal	0	6		
Dark-grey carbonaceous sandstone	0	4		
Carbonaceous shale	0	8		
Coal	2	4		
			7	0
Carbonaceous shale			0	6
Grey shale (bottom not seen)			2	0
			16	0

2.

Section 50 feet S. W. of Mr. Blanford's section.

	Ft.	In.
Clays	2	0
Sandstone	8	0
Clays	1	0
Sandstone	1	0
Clays	4	0
Carbonaceous shale	5	0
Sandstone (bottom not seen)	...	
	21	0

In following the stream towards its source the same seam of coal is repeatedly seen, the dip continuing northerly, and in one place I detected another small fault with a throw of about 3 feet.

In the Jumkole stream (the next stream to the west, running into the Seemkole just below its junction with another small stream from the direction of Dongur Parasia village) very shaly coal is again seen dipping very slightly to north-north-west, and a short distance above this the red clays of the Moturs come in, dipping to north-20°-west at 18°.

This Rawanwara seam offers no encouragement for exploration; it was reported on by Major Ashburner in 1865, by Mr. Blanford in 1866, and by Mr. Arthur Sopwith in 1867.

Another outcrop not found.

V.—The other Rawanwara outcrop mentioned by Mr. Blanford I was unable to find; from his description it is evidently an inferior seam.

Dongur-Parasia.

VI.—In the stream flowing towards the south just to the west of the village of Dongur-Parasia (E. Lon. 78° 50′) locally known as Ghogra Nala, on the left bank of the stream, is a hole which has been dug in order to collect water for irri-

gation purposes. In digging this some coal was passed through, though from information obtained from the villagers it seems to be of no great thickness. The section passed through is said to have been as follows :—

	Ft.
Yellow sandstone	2
Coal	1
White sandstone	several feet.

The dip of the ordinary Barakar sandstone to the south of this hole is to north-west at 8°, but I could not find the coal outcropping.

Coal in well near Dongur-Parasia.

VII.—About half a mile below the village, a small stream from Dongur-Chicklee runs into the Ghogra Nala; close to the junction and to the south of the smaller stream, there is a well near the mouth of which there is a large amount of shale lying on the surface. I was unable to find any outcrop of coal or shale in the immediate neighbourhood of the well, but a villager who said that he had helped to dig the well informed me that the total depth dug was about 16 feet, and that the rocks passed through were—

	Ft.	In.
Red and yellow sandstone	12	0
Coal	4	6
Shale not passed through.		

The red and yellow sandstone appears to have been a hard sandstone much impregnated with silica, and closely resembling a rock that is seen in the Ghogra stream lower down and in the Bhandaria stream near the fault cutting off this portion of the field towards the south. The dip of the sandstone near the well is 8° to north-west.

Another outcrop.

VIII.—About half a mile west of Dongur-Parasia in the small streams running from Dongur-Chicklee, and just at the foot of the long hill capped with trap, some 2 to 3 feet of carbonaceous black clays and shales are exposed, with a dip of 5° to the north. These shales and clays rest upon sandstone where the bottom is seen, but the section was nowhere well exposed. I believe this is the same as Mr. Blanford's No. VII Parasia seam.

Outcrop in Ghogra Nala.

IX.—In the stream locally known as Ghogra Nala, flowing into the Bhandaria river just at the boundary between the village lands of Bhandaria and Dongur-

Parasia, some coal is exposed just above the junction with the larger stream. This is Mr. Blanford's No. VIII Bhandaria seam ; it is one of the seams reported on by Major Ashburner in 1865 and visited by Mr. Sopwith in 1867.

I could not fit in the section with the one given by Mr. Blanford exactly, as owing to the flatness of the stream bed, some portion of the section which he saw was concealed at the time of my visit, and *vice versâ*.

I give the two sections side by side as the two together give a better idea of the whole than either alone.

Section as seen by Mr. Blanford, 1866 (pp. 130-131).

	Ft.	In.	Ft.	In.
1. Coarse shaly sandstone many feet				
2. Shale, top not seen . .			2	0
3. *Coal*	1	0		
4. Sandstone of various colours, yellow, red, and black .	1	8		
5. Coal very good (the base is concealed by gravel, and the thickness may be a few inches more, but only a few inches) . . .	2	6		
6. Sandstone . . .	3	6		
7. Carbonaceous shale . .	0	8		
8. Sandstone . . .	0	9		
9. Carbonaceous shale . .	0	7		
10. *Coal* very good . .	3	3		
11. Shale	0	6		
12. Sandstone . . .	0	3		
13. *Coal*	0	6	15	2
14. Shale			0	2
			17	4

1885.

	Ft.	In.
Sandstone, dip west 20° north at 10°, over	7	0
Shale, containing some coaly matter, bottom not seen . .	1	6
Break in the section with shaly sandstone at bottom . . .	3	0
Hard shaly sandstone . . .	1	8
Coal . . . . 2 ft. &	2	6
The upper 1 foot of this coal only is to be seen, the rest being under water.		
Section concealed a great deal but appears to be—		
Shale.	0	5
Shaly sandstone	0	7
Very carbonaceous shale . .	1	0
Coal	0	8
Shale	0	2
Coal	0	2
Sandstone	0	7
Black shale	0	4
Inferior shaly coal	0	8
Good *coal*	3	9
Shale	2	0
Sandstone base not seen		
	26	0

Mr. Blanford gives another measurement for his No. 10 as seen lower down the stream, *viz* :—

		Ft.	In.
No. 9 shale			
No. 10.	Coal	1	0
	Shale	0	2
	Coal	3	6
		4	8

I could not find the exposures of the other two thin seams below and the thin shaly seam above mentioned by Mr. Blanford.

Bhandaria Bhutaria outcrop.

X.—Following the stream which flows past Bhandaria upwards from the point where the Ghogra joins it, just beyond the village of Bhandaria, 2 feet of coal is exposed on the right bank of the stream. A little further up the following section is exposed on the same side :—

	Ft.	In.
Shaly sandstone	6	8
Shaly sandstone with black streaks	3	0
Hard white sandstone	0	5
Black shale	0	5
Shaly sandstone	0	3
Very shaly sandstone	0	5
Coal, dip south 10° east at 4°	2	5
Sandstone, bottom not seen		
	13	7

A short distance up the stream, coal is again exposed; this time on the left bank, within the limits of the village of Bhutaria. At this point I had a hole dug into the coal and obtained the following section :—

	Ft.	In.	Ft.	In.
Coal	3	0		
„ with much pyrites	2	0		
Shaly coal	1	0	6	0
Dark shale with much pyrites			2	0
Lighter shale			1	0
			9	0

In sinking a well to the east of Bhandaria village, the following rocks are said to have been passed through:—

	Ft.	In.
Coal	1	0
White standstone	3	0
Coal	1	6
Shale	3	0
White sandstone	12	0
	35	6

I believe these to be all exposures of the same set of seams, *i.e.*, that there is one (or more) main seam of coal about 5 feet in thickness with one or two smaller irregular layers of coal above and below. The seams in the Ghogra are probably part of the same. There are two drawbacks to the usefulness of this coal, *viz.*, the large amount of interstratified shale accompanying the coal, and the large quantities of pyrites present in the lower part of the main seam.

Barkoi.

XI.—The only other exposure in this area is at Barkoi village, on one of the roads from Umreth to Pachmarhi. This outcrop was discovered in 1852 by Dr. Jerdon and Lieutenant Sankey. It was mentioned by Major Ashburner in his report, and visited and reported on by Mr. Blanford in 1866 and by Mr. A. Sopwith in 1867. The coal at this spot was worked for some years, but owing to the difficulties of transport the works were eventually abandoned.

At the time of my visit the workings had all fallen in; but Mr. Blanford who was able to enter them gives an account of them in his report.[1] He states that there are 6 feet of good coal, and he had a favourable opinion of the coal and the prospects of working it. He gives the dip as averaging 3°, to south-south-west. In a well to the north of the village 6 feet of coal are stated to have been met with at a depth of 21 feet, but the outcrop to the north could not be found; it is quite probable that there is a roll in the beds to the north of the village, and that the coal dips down to the north and extends for some way at a short depth from the surface.

[1] Rec. Geol. Surv. India, XV. p. 132.

In a stream, locally known as the Ghogra, to the south-east of the deserted portion of the village (*i.e.*, the south-east portion, which was formerly the larger, but has been deserted in favour of the north-west portion in consequence of want of water), there is an exposure of coal (also mentioned by Mr. Blanford) :—

	Ft.	In.
Coal	1	8
Hard shale	1	0
Coal	0	7
	3	3

It is badly exposed and the coal of a very soft quality, the dip is not seen.

Ekleyra.

XII.—Coal is also said to occur in a well to the west of the village of Ekleyra, which was excavated many years ago in the Motur rocks; this is probably the same shale as is seen in the stream to the east of the village.

§ 10.—*The Harai Field.*

This is a small and unimportant area thrown down by the Pench fault and only occupying an area of less than one-third of a square mile. It is interesting on account of its being the most easterly case where we find the Barakars resting on the Talchirs, which terminate the field to the south, while to the north it is bounded by the Motur rocks. To the east and west it is overlaid by trap.

Outcrop of shale.

In the stream formed by the junction of the Bhandaria and Dongur-Parasia streams, just at the point where the village lands of Dongur-Parasia, Khursadeye, and Khumra meet, there is a band of highly carbonaceous shale very much disturbed, but further down the stream the dip of the Barakar sandstone is only a few degrees to north-west.

Below the small stream flowing from the east of Dongur-Parasia, a trap dyke crosses the stream beyond which shale with a northerly dip is exposed.

Shale in a well at Harai.

XIII.—Harai (Hurreye): Mr. Blanford mentions a seam, said to have been found in a well at this village. I found three wells here. An old one to the north-east of

the village about which I could obtain no information. A second one east-by-south of the village was said to be the one from which Major Ashburner had taken some coal. I was informed that it was 42 feet deep, but the villagers knew nothing more about it. The third well is to the south-east of the village; it was dug only about 1873, and was said to be 40 to 45 feet in depth and to contain shale at the bottom. From the information I was able to obtain on the spot, I am inclined to think that the coal reported from here was not coal, but carbonaceous shale, as what I saw lying on the surface as having been extracted from this last well was certainly shale. It is however of but slight importance whether it is shale or coal, as it must be cut off at about a quarter of a mile to the north by the fault, and it is chiefly interesting as giving a measure of the thickness of the Moturs, through which the coal was reached at this point.

§ 11.—*The Gajundoh Field.*

Outcrop near Gajundoh.

Following up the Puthreye stream from just above its junction with the Kopadoh it passes over metamorphics as far as a point nearly north of Gajundoh village (E. Lon. 78°46′), below the junction of the stream from Ghogri village, where massive Barakar sandstone is seen in the right bank. Further up, above the Ghogra, shales are seen dipping to the north-10°-west at 30°.

XIV.—A little further up still sandstone is again seen dipping north-20°-west at 40°, and covering shales with the same dip. The shale is 8 feet thick and immediately below it are 5 feet of coal, then 3 feet of shale. Sandstone indurated with silica is seen close by beyond which the metamorphics come in again.

	Ft.	In.
Sandstone, N-20°-W. at 40°, top not seen—		
Shale	8	0
Coal	5	0
Shale	3	0
	16	0

In the small stream running into the Puthreye from the west just above the Ghogra, the same seam of coal is exposed striking nearly north-east and south-west, much disturbed, and with the accompany-

ng sandstone much infiltrated with silica. Barakar sandstones are also exposed at intervals up the Ghogra till they are covered by the red clays of the Motur group. The measures are much disturbed and must have been faulted down here and subsequently protected from denudation by the trap. This seam was discovered by Major Ashburner. Its position would be very favourable for working being south of the hills and within 3 miles of the large village of Umreth (Oomrait), and it is possible that if it extends under the trap for some distance the coal is less disturbed further from the fault; the chances are, however, that it is cut off to the north by another fault or by the continuation of the Pench fault. The area covered by Barakar rocks is only about $\frac{1}{10}$ of a square mile.

§ 12.—*The Hingladevi Field.*

The next area of Barakar rocks towards the west is the Hingladevi field, so called from a small jungle shrine situated within its limits, and close to one of the coal outcrops. The shrine appears to be associated in some way with coal in the minds of the Gond villagers, whose name for coal is Hinglaj. The area occupied by Barakar rocks is 2·8 square miles.

This field is on the western continuation of the Barkoi field, from which it is separated by the rising ground of Moturs—which overlap the Barakars here dipping 3° to north-east close to the boundary in the Chanpat Ghogra, while further to the north-east by Ekleyra the dip is north-westerly, north-east of Umbara—and by the trap which covers it to the east. This trap follows along to the south, forming the south boundary for some distance till the actual contact with the Talchirs is exposed, to the east of Bahadree. The Talchirs continue to form the boundary to beyond the village of Jumkoonda, where they are brought into contact with the Moturs by a fault. The entire north boundary is formed by the Moturs, which seem to overlap the Barakars to some extent.

The Hingladevi outcrop.

XV.—The most eastwardly exposure of coal in this area is in the Hingladevi or Gogra stream; it was known previous to Mr. Blanford's visit, and some excava-

tions were made there, at his suggestion, by Mr. Adams of Barkoi, from whose reports the seam appears to be over 5 feet in thickness. It is seen in the stream which runs past the deserted village of Dhow and locally known as Hingladevi Nala; it is just within the boundary of the forest lands of Ghogri village. I could only see 2 feet of coal, which was covered by massive sandstone, the base of the coal is concealed by water which forms a deep pool at the spot. The strata as far as can be judged at the exposure seen are horizontal.

Lower down the same stream to the south-east of the deserted village of Dhow (E. Lon. 78° 44′) another section of the same seam is seen in the bed of the stream; it is much broken and concealed in parts and the dip is very slight, being only 2°—5°, to north-west. The stream runs from north-east to south-west at this point—

	Ft.	In.
Shaly sandstone, many feet—		
Coal	1	0
Sandstone, thickness not seen.		
A small fault here runs across.		
Shaly sandstone, several feet, the lower portion being covered with sand for a horizontal distance of 26 feet—		
Coal	2	0
Shale, several feet.		
Fault running east-west across the river.		
Shale, the base concealed by sand—		

but about 100 yards lower down the stream the coal is seen again just at the level of the surface of the water on the right bank, and the following section is exposed—

	Ft.	In.
Sandstone	2	0
Coal	2	0
The remainder concealed by water but there may be about	1	0

Between this point and the Hingladevi exposure, coal is seen in two places in the stream, but only 2 feet are exposed in each case; the dip is to the south-east and very slight. I believe that all these exposures belong to the same seam of coal which is fully exposed in none of them; the beds roll slightly but never have a high dip. The coal seems of good quality and might be worth working were it in a more accessible spot.

XVI. In the Bhangeedoh stream (locally Chanpatghogra) there is some shale exposed to the south-west of Umbara, dipping to north-east at 30°. Mr. Blanford and Major Ashburner mention that coal is said to have been found in a well at Paláchaori (Pala-Chowrye). A well some way to the south of the village was pointed out to me as being the spot. The villagers stated that there were about 9 inches of coal at a depth of about 8 feet.

Coal at Pala-Chowrye.

At the village of Nuzzerpur there is a well passing through an inclined trap dyke; immediately below the dyke there is some carbonaceous shale. I was informed that some coal had been formerly obtained from another well at this village, but that it would not burn. This was, therefore, probably also shale. This is one of the localities mentioned by Major Ashburner.

Coal at Nuzzerpur, probably shale.

§ 13.—*The Kanhan Field.*

The next field towards the west is the Kanhan field, named after the river of that name which in the earlier part of its course flows across it. The area is 12·2 square miles. Throughout nearly the whole of its length,from east to west, it is covered along its northern edge by Motur clays and sandstones, the passage from Barakars to Moturs being very sudden, which is suggestive of overlap, but towards the west the boundary is cut into by a fault associated with a pseudomorphous-quartz vein which brings down the Moturs into contact with the Talchirs. Along the south edge the Barakars rest upon the Talchirs except for a short distance at the western end where a trap dyke intervenes, and for a short distance at the eastern end where the fault which cuts off the Hingladevi field to the west, cuts off this one to the east. Owing to these two faults the field tails off to a pointed form at either end.

XVII.—In the small stream between this village and the site of the deserted village of Badeo, just south of the pathway between the villages of Datla and Punnara, 7 feet of coal are exposed in the left bank, and by clearing away the sand I found that the coal formed the bed of the stream. I had a

Coal at Datla.

small excavation made here to a depth of 2 feet 8 inches, beyond which I could not persuade the villagers to go, they being unaccustomed to the labour, and owing to an accident which is said to have happened at Barkoi during the time that the coal was being worked there, they object to having anything to do with working coal. This gives 9 feet 8 inches of coal seen, or at least 10 feet of actual coal, since neither the top nor bottom of the seam was seen. The dip is to the north at 10° and the coal is overlaid by surface soil.

Exposed again in Takea river.

In the Takea river almost due west of this spot the same seam is exposed again at a distance of about one-third of a mile from the first exposure. There is no reason to suppose that it is not the same seam, as the dip is the same and there is no apparent break in the rocks, while it is just where it might be expected to reappear. The section is much spread out and partially concealed, but it appears to be :—

	Ft.	In.
Shaly sandstone wtih carbonaceous matter—		
Coal	4	0
Forty feet lower down the river—		
Coal	4	0
Fifty feet lower down the river—		
Coal	5	0
Fifty feet lower down—		
Sandstone—		
Shale—		
Coal	3	0

Some of this coal may be a repetition by faulting, as the section is not at all clear.

This seam was reported on by Major Ashburner in 1866, and either this or the one at Punnara is probably that referred to by Mr. Sopwith in his report in 1867 as being a "fair seam 5 feet thick about 7 miles west of the Hingladevi seam."

Outcrop at Panara.

XVIII.—Just below Panara (E. Lon. 87° 36′), in the Takea river, is a spot where the water falls over some massive sandstone into a shallow pool below; immediately under the sandstone and in contact with it 8 feet of good-looking coal is exposed dipping to north at 10°, but on account of the water in the

pool I was unable to see how much thicker it is. About 50 yards lower down the river, coal which must be beneath the other is seen in the following section :—

	Ft.	In.
Shaly sandstone	3	0
Shale	1	6
Sandstone	0	6
Shale	0	6
Coal	2	0
Sandstone, thickness not seen.		
	7	6

The dip here is rather higher than further up the river owing to a trap dyke just below the bottom sandstone which has tilted up the strata to some extent. This seam was visited by Major Ashburner.

Coal near Pooreena.

XIX.—In the stream running to the west of Pooreena (E. Lon. 78° 34′) I found numerous fragments of coal, but although I visited the stream twice the first season and again the second season, I was unable to find the outcrop of the seam from which they had been derived. Major Ashburner, however, reported a seam in this stream 8 feet in thickness.

Coal near Nundora.

XX.—In the next stream to the west, beyond Nundora village (E. Lon. 78° 33′) and just on the boundary line between this village and that of Ghorawari, there is a 3-feet seam of coal exposed in the left bank dipping to north-east at 10°. It is probably really somewhat thicker as the surface soil rests immediately on the coal at the exposure. This seam was reported on by Major Ashburner. In one of the small streams to the north-west of this there is a band of shale containing 3 inches of coal.

Coal at Damooa.

XXI.—In the small stream following to the north of Damooa (E. Lon. 78° 30′), and running into the Kanhan just by the village, a small seam is exposed, there being 1 foot 4 inches of coal between sandstone and micaceous shaly sandstone containing strings of coaly matter; the dip is to north-20°-west at 5°, and the coal appears to die out in a very short distance.

Major Ashburner speaks of two exposures, at this place and of the coal being over 4 feet thick, but I was only able to find one exposure,

and this only after visiting the place twice, in sucessive years, as the first year the spot was covered with several feet of sand, though I found fragments of coal lower down in the bed of the stream.

§ 14.—*The Tawa Field.*

This is the most extensive continuous area of Barakar rocks exposed in the Satpura basin, being 19 miles in length from east to west and 8 miles across in its widest part. It covers an area of 79 square miles; but in spite of the large area of ground covered the number of coal seams exposed is not large, although two of them are of considerable thickness. The name adopted for the area is that of the Tawa river, which flows across it for some distance at its western end.

Extent of area.

Following down the Tawa from the point where it leaves the Talchirs, north of the village of Sarni, there is a mass of trap exposed in the bed of the river and on its right bank extending for some distance along the hill to the north. Beyond this, typical Barakar sandstones, dipping to north-west at 5°, are exposed along the river, and a thin bed of coal under an overhanging mass of sandstone. The Barakars continue along the river, and the dip gradually becomes more northerly, and at a higher angle till beyond Sobhapur just before the Moturs cover the Barakars the dip is north at 25°.

Wherever the rocks are exposed north and south of the Tawa in the small tributary streams, they are typical Barakars, chiefly sandstones and mostly with north and north-westerly dips, becoming steeper to the west.

In the neighbourhood of Bhogi and Khapa numerous small boulders closely resembling those of the Talchir boulder beds are to be seen distributed sparsely over the surface of the ground. I at first thought that they might be due to denudation of Talchirs at this spot, but after a careful search in the neighbouring watercourses I was unable to find any rocks which presented any signs of being other than Barakars, and the coal seam exposed in the Tawa near Bhogi-Khapa distinctly indicates the presence of

Talchir boulders lying on the Barakars.

Barakars. I have, therefore, preferred to colour the whole as Barakars on the supposition that the boulders have been washed out of the Talchirs further up the river and carried down to be redeposited on the surface.

The whole northern boundary is formed by the Motur rocks, which appear to overlap along parts of the line, though, as a rule, the passage from Barakars to Moturs is very gradual, and massive sandstones which may belong to either group intervene between the typical Barakars and the red clays. The Motur rocks pass along to the west and form the entire western boundary. The south boundary is formed by the Talchirs, and at the east end it is faulted.

Outcrop of coal in Tamia river.

XXII.—In the Tamia river, which runs into the Tawa close by the village of Chomou (E. Lon. 78°24′), there is a seam of coal which was discovered and reported on by Major Ashburner in 1866.

The seam is situated in the bed of the river nearly opposite and to the east of the small village of Tanse (E. Lon. 78°24′). Going up the stream the seam is first seen on the left bank, close to a small quartz vein which runs nearly north-east and south-west. Next to the reef there is a small thickness of sandstone much impregnated with silica, against this some shale rests abruptly, dipping to the east and overlying the coal, of which only a few inches are seen here. A few yards further up the river on the right bank five feet of coal are exposed. By means of a small excavation I was able to obtain the following section, but owing to influx of water I was unable to sink through the coal.

	Ft.	In.
Surface soil	12	0
Coal	5	0
Carbonaceous shale	1	6
Coal	2	0
Carbonaceous shale with pyrites	0	4
Coal, over	0	6
	21	4

or over $7\frac{1}{2}$ feet of coal.

Owing to the surface soil resting on the coal and the difficulty of

getting right through the coal, it is impossible to tell at present the actual thickness of the seam, but it may without much chance of exaggeration be considered as at least 8 feet. It would be difficult to test this seam, owing to its unfavourable position up the Tamia river, and to the fact that to the dip, where borings would naturally have to be put down, the eastern bank of the river rises up abruptly in a cliff of some height, and is composed at the bottom of about 50 feet of shales, above which sandstone forms a steep slope, so that 100 feet of superincumbent strata would have to be bored through before coming to the level of the coal in the river. Any explorations here should therefore take the form of galleries driven on the coal.

The dip is to the south-east at about 10°, and from what could be seen at the lowest point where the coal is exposed just above the quartz vein, it must have been brought here by a fault with a downthrow to the south. The neighbourhood is also considerably cut up by trap-dykes and quartz veins, which would interfere with the profitable working of the coal even if other circumstances were favourable.

Coal near Danwa.

XXIII.—In the stream running to the west of the village of Danwa, north-west of Omerdo (E. Lon. 78° 22′) and joining the Tawa near that village, at a distance of about 1 mile from the village in a straight line, there are some strings of coaly matter of no value in the sandstone.

Coal at Dodramou.

XXIV.—In the Baradhar river (E. Lon. 78° 20′) above Dodramou, and half a mile below the point where the small stream from Bakari comes in, there is a coal seam which is possibly the one referred to by Major Ashburner in 1866 as a seam upwards of 2 feet in thickness near Dodramou. At the point where the coal is exposed the section is as follows:—

		Ft.	In.
Coarse sandstone	Many feet.		
Carbonaceous sandy shale		6	0
Black slaty shale		6	0
Sandy shale		2	6
Coal		2	0
		16	6

The base of the coal is concealed by a pool of water, so the seam is probably somewhat thicker. A few yards lower down the stream, a bed of sandstone appears in the sandy shale layer, and rapidly thickens out to the exclusion of the shale. The other beds are also very variable in character within short distances, and the mass of sandstone at the top appears to rest unconformably on a denuded surface, as the junction is very irregular, in fact it appears as though this would prove to be nothing more than a large pocket of coal.

Small seam near Bhogi-Khapa.

XXV.—To the south-east of the deserted villages of Bhogi-Khapa (E. Lon. 78°13′) on the right bank of the Tawa river, at a distance of about half a mile below the Talchir-Barakar boundary, a two-feet seam of coal is exposed under an overhanging mass of sandstone. The coal rests immediately on massive sandstone and is covered by sandstone of the same character. The dip is to north-west at 5°.

In a small dry watercourse to the south of the Tawa, between the river and a little hill to the south, close by the last exposure, the same seam is again exposed. It is here of poor quality and only 1 foot is seen, as it is situated in a small hollow in the bed of the stream, which is much blocked up with large boulders from the hill. The dip at this point is to south-20°-west at 20°. This is probably the Bamanwara-Khapa seam of Major Ashburner's report.

Large seam near Patakhera.

XXVI.—A seam of coal (E. Lon. 78° 14′ 15″) was discovered by Major Ashburner and reported on by him in 1867 as the Mohodongri seam, but as it is nearer to the villages of Patakhera and Sarni I have given them the preference. The coal appears in the small stream which runs past Patakhera, though the village at the time of my visit had been moved some distance to the north-east of the spot marked on the map. This stream runs into the Tawa at the corner where it turns north after flowing to the west past Silwani.

Going up this stream from its confluence with the river nothing is at first seen but Talchir shales, these gradually pass into sandstone

which quickly takes on the character of the Barakars. Above the first stream on the right bank, there is some very carbonaceous shale, with a slight dip towards the west, and above this is a trap dyke running north-west to south-east which could only be traced a short distance from the stream, but which is probably in connexion with some of the dykes to the north-west, above this some more of the carbonaceous shale occurs ; for 50 yards up the stream no further exposure is seen, after which the following section is exposed :—

		Ft.	In.
Sandstone	Several feet.		
Coal (dipping west-10°-south at 60°)		3	0
Shale	A few inches.		
Shaly sandstone		9	0
Coal		1	0
Coarse sandstone		4	0
Coal		1	0
Massive sandstone, base not seen.			
		18	0

About 20 yards further west up the stream the following section is exposed :—

		Ft.	In.
Sandstone,	several feet ; top not seen.		
Shale		1	6
Coal (dipping west-10°- south at 60°)		1	0

Sandstone containing bands of micaceous shale, varying in thickness from a mere streak to 2 or 3 feet, underlies the coal in this section. The shale has somewhat the appearance of the Talchir shales, but the sandstone is of Barakar type.

Above this section, and just above the junction of the second small stream on the right bank, there is repetition of one of the seams seen lower down, caused by a turn in the stream; the bed of the stream is however so choked up with debris that all that can be seen is 3 feet of coal, above this, 10 yards to the east, sandstone and shale are again seen dipping west-10°-south at 60.°

A little further up a very thick seam of coal is seen ; the top foot is very bright and bituminous, and is faulted against the sandstone

above it; below this is some ordinary dull coal with bright bands and some shale at the bottom. The dip here has slightly altered, being west-20°-south at 50° only. The thickness of the coal at the outcrop is 11 feet. Further up the stream the dip of the Barakar sandstone falls off to west-20°-south at 20°, whilst in the small stream to the east it is south-west at 25°, and north of Ghogri south-20°-east at 15°. It appears that there has been faulting here though no sign of it could be found beyond the high dip except in the immediate vicinity of the seam. It is probable that the vertical dislocation of the beds is not great, and that the disturbance is caused by the continuation of the Lodadeo-Rawandeo fault. It might be worth while, were borings made in the field, to put down at least one here at some distance to the dip, say, 200 yards from the outcrop, as it is possible that the high dip is merely due to faulting, and at that distance the coal would have resumed its normal dip.

§ 15.—*Summary.*

Seven fields.

These seven small fields exhaust what may be called the Chhindwara portion of the Satpura coalfields; as, with the exception of the western portion of the Tawa field situated within the limits of the Betul district, the whole lie within the district of Chhindwara. The four areas of Dolari, Machna, Suki, and Sonada, have been fully described and mapped by Mr. H. B. Medlicott.[1] These for convenience are grouped together as the Shahpur coal-fields being situated entirely within the district of Betul near the large village of Shahpur. I have nothing to add to Mr. Medlicott's description, and in fact I have done little more in that part of the basin than fill in the main boundary where left incomplete by him and adding a few quartz veins and trap dykes, and the portion of the map on which the Shahpur fields are represented is almost entirely a reduction of Mr. Medlicott's large scale map of that area.

The Barakar rocks consist of felspathic sandstones and shales not

[1] Rec. Geol. Surv. India, VIII, 3, 65.

differing in character from those described in other fields. There is a scarcity of fossils: the only localities where I obtained any were at Hirunbhutta, Sirgora, and Bhandarea, but they are very fragmentary and merely recognizable as plant remains. The thickness of the Barakars where most fully exposed in the Tawa field does not probably exceed 1,500 feet; and the apparent thinness to the east, though to some extent actual, is in places due to overlap of the Moturs, as between the Barkoi and Hingladevi fields where the Motur clays come right across the strike of the Barakars; and though the overlap is obscure the general appearance of the boundary is such as to suggest it.

§ 16.—*The Motur Group.*

Above the Barakars comes a group of rocks consisting for the most part of mottled red, yellow, green, and white calcareous clays, and white felspathic sandstones, which have been named the Motur group by Mr. Medlicott.

Red clays readily distinguishable.

The clays are readily distinguished from all the rocks occurring among the Barakars; they are usually of a dark red claret colour, sometimes greenish or yellow, and white, the various colours are mixed in small patches, so as to give a mottled appearance to the whole rock; the white portion of the clay frequently contains a large quantity of white sand.

Calcareous nodules.

One especial characteristic of the clays is their calcareous nature; they contain numerous small plates of argillaceous carbonate of lime and larger nodular masses of very irregular shape disposed in horizontal layers in the clays. These nodules when broken open are seen to consist of a matrix of argillaceous carbonate of lime, with veins of crystalline carbonate of lime filling up the centre and radiating irregularly towards the outer surface, where they form hard ribs, which on exposed surfaces have resisted the action of the weather better than the soft clayey portions, and thus come to form slightly raised lines over the surface. Where any large thickness of these clays has been subjected to denudation, as on the hill north-

east of Umbara, between the Hingladevi and Barkoi fields, and in the Pench river by Jatachaper (E. Lon. 78° 46′) and Chicklee, the clay has been removed and the ground is thickly strewn with the nodules. The clays at the time of deposition must have been of a very calcareous nature, and the carbonate of lime has since been separated out by segregation from the mass of the clay. As a rule, the clays are split up into numerous polygonal fragments by irregular joint planes. They are also somewhat saline, and exposures in cliffs and banks are much frequented by cattle and other animals who lick up the clay with avidity, and must swallow large quantities of it, as their excrement is often of a decided red tinge owing to the admixture of the coloured clay, which has passed through their bodies. The water from wells sunk in the clay has also a slightly bitter taste, and that from one well at Pala-Chowrye is undrinkable on this account. The clays are not confined to any particular horizon in the Motur group, as they occur immediately above the Barakars in the Pench river and also on the top of the Motur hills, by Motur village, where the trap covering has been denuded away. The appearance of the clays so immediately over the Barakars may to some extent be due to overlap, as further to the west there is a sandstone intermediate between the two, but the source from which the material was derived was probably to the west and only the fine material was carried out to the east.

The clays form the greater part of the low ground, through which the Pench river flows after leaving the Motur hills, till it passes across on to the trap. The country to the north of the Pench river, as far as the trap, also consists to a great extent of these clays. They are much more prevalent at the eastern end than towards the west, the limit to which they extend in great force being about the line of the Kanhan river.

Sandstones.

The sandstones which are in greater force towards the west of the area, though also occurring to some extent at the east, are at times undistinguishable from the sandstones of the Barakars, but the felspar contained in them is frequently less decomposed than is the case in the Barakars. The sand-

stones are slightly calcareous, but not by any means to the same extent as the clays.

At the eastern end, where the clays are in great force, the line of demarcation between the Barakars and the Moturs is well defined where seen.

In the Dighawani stream the Barakars are exposed at intervals, while close by to the north in the Teorakole, Seemkole, and Jumkole streams, the red clays are exposed for a short distance before being covered by the trap. The boundary is again exposed beyond Dongur-Parasia and extends westwards north of Chandameta village, passing then north-west by Bhajipani; it is well exposed in the small streams which it crosses. In the stream running from Barkoi to the east of Ekleyra, there are some Barakar shales, to the north-east of the village of Ekleyra, which are found again to the west of the village in a well made through the Moturs; above them is sandstone for a short distance and then red clays, while in the small stream which passes to the west of the village, the red clays and sandstones of the Moturs extend the whole way from the commencement of the stream to its junction with the larger one into which it runs, thus coming right across the strike of the Barakar beds, and suggesting the possibility of overlap.

Motur Barakar boundary.

The passage from Barakars to Moturs is also sharp along the boundary from near Umbara just north of the Hingladevi field, to beyond Jumkonda, at the western end of the same field.

Going down the Raneedoh stream from Oomeria, between Jamye and Pala-Chowrye, towards the Takea river, the Motur clays are exposed for some distance, and then the beds become much broken and impregnated with silica, which forms a rib of quartzose rock 2 feet wide, running across the stream, beyond which the Talchir boulder bed is seen faulted right against the Moturs.

It is evident that we have at this point a faulted boundary, and the fault is the continuation of the one running through Saleye hill and seen in the Soonkee (locally Takea) river.

Boundary faulted.

On following down the Punghat (south of Jamye) and Sungun rivers we get off the red clays on to Barakar sandstones and shales, the change being very sharp at these points; after the junction with the Soonkee just before coming abreast of Saleye hill, there is a run of pseudomorphous quartz rock across the river, and just opposite the hill a wide trap dyke, beyond which there is more pseudomorphous quartz and the sandstone near is much impregnated with silica; immediately beyond this the boulder bed of the Talchirs is seen, evidently faulted up against the Barakars by a continuation of the fault seen in the Raneedoh stream, which passes obliquely right across the outcrop of the Barakars, and has shifted these beds horizontally almost along their strike for a considerable distance.

The Moturs occupy the high ground below the trap to the north of the Kanhan field of Barakars, till they are again faulted against the Talchirs at the Pothia river for a short distance.

Beyond this point the Motur-Barakar boundary becomes much less well marked, as the red clays are much less developed and the intermediate sandstones come in in greater force.

The general dip of the Moturs is north to north-westerly and is seldom high, being usually at about 10°.

Upper boundary.

The upper boundary of the Motur group I have not yet worked out, but the clays extend for some distance under the trap of the Motur hills and are seen in the river by Bichberi south of Pachmarhi. This indicates a thickness of about 2,000 to 3,000 feet at the most modest computation, but it is probably more.

In the deep gorges, through which the Pench river leaves the trap of the Motur uplands, the river has cut back, leaving the Moturs exposed and near the village of Bolkheri I found a few fossil fragments of plant stems; this is the only place where I found any fossils in these rocks.

Outlier near Rajegaon.

There is a small outlier of Motur clays and sandstone, at the highest point of the hills to the north of Rajegaon (E. Lon. 78° 17′), near the Tawa river.

To the east the Moturs thrown down by the Pench fault are exposed near Harai, Chinda, and Sirgora.

§ 17.—*Inter- or infra-trappeans.*

Above the Moturs there is a great thickness of rocks which I have not yet studied, but which have been partially described and classified by Mr. H. B. Medlicott.[1] At the eastern end of the field, however, on the hill above Sirgora, between the Barakars and the trap, there is a bed of rock not exceeding 20 feet in thickness, and consisting of a hard conglomeratic sandstone containing white quartzite and red jasper pebbles. The same rock is again seen on the hill above Babeye (E. Lon. 78° 59′), and on the hill on which Garha stands (E. Lon. 79° 2′) where it is very hard and siliceous, and in the river by Thesgora (E. Lon. 79″ 1′) and Mohli, in these cases being between the metamorphics and the trap. It is probably of Infra- or Inter-trappean age, but from its position and the absence of fossils it is impossible to say more with certainty than that it is older than the trap which occurs above it.

§ 18.—*Trap.*

Superficial trap.

The trap rock, which is of the usual basaltic character, occupies a large area. It is found capping the whole of the Motur hills, and many of the lower hills to the south.

Dykes.

There are numerous dykes running approximately east-west, where they appear on the surface, but in few cases are they traceable continuously for any long distance, though at times a continuation of the same dyke is to be found further on in the same line. In many cases they are certainly due to intrusion along the bedding planes of the rocks through which they come to the surface, and this is especially evident in the case of the long dyke which crosses the Tawa near Saidal Gondi (E. Lon. 78°25′), and the dyke north of Gorak (E. Lon. 78° 32′) which is exposed for some distance in the banks of the stream crossing it. The section

[1] Mem. Geol. Surv. India, X, 2, 133.

here exposed shows 4 sheets of trap, with layers of sandstone between and sandstone above and below, and following the dip of the beds (north-west, 15°). The sheets of trap are irregularly connected at intervals, so as to present a roughly reticulated structure; the thickness of the sheets is also very variable, from 2 and 3 feet to as much as 30 feet in places. These sheets come to the surface on each side of the stream where they form a wide dyke.

Dykes connected with superficial trap.

The complicated dyke north of Omerdo (E. Lon. 78° 22′) appears to pass up into the long superficial sheet of trap covering the hills to the north-east, but unfortunately there is a quartz vein at this point and the actual junction is covered with debris, but I think there can be no doubt that the two are connected. The dyke which crosses the Sookree river (E. Lon. 78° 49′) was traced almost into the superficial trap of the hill to the east, but the talus here again prevented my seeing the actual junction. The dyke crossing the Ghatamalee river by Titra and Dudi (E. Lon. 78° 53′) also passes at each end into the superficial trap.[1] In the Sukli stream above Pagara (E. Lon. 78° 48′) there is a very fine example of radiating columnar structure in the trap. The columns are roughly hexagonal and vary in size from 7 inches to 1 foot 10 inches across.

§ 19.—*Faults.*

Saleye fault.

The great number of the faults in this area have the down-throw to the north. The exceptions are the Pench and Machna faults. Besides these two and those described by Mr. Medlicott in the Shahpur field there is the well defined Saleye fault separating the Hingladevi and Kanhan coal-fields, which brings the Moturs into contact with the Talchirs. Further west of this there is a run of quartzose induration which starting in the Moturs south of Bhakra forms the Motur-Barakar boundary for some distance, and along the same line the Moturs are again faulted into contact with the

Pothia fault.

[1] See Mem. Geol. Surv. India, Vol. X, p. 179.

Talchirs in the Pothia river, beyond this the quartzose rock is again seen forming the boundary between the Talchirs and Barakars, and eventually dying out in the Barakars north of Danwa.

Lodadeo-Rawandeo fault.

On the Lodadeo-Rawandeo ridge south of the Tawa river there is a line of quartz vein running along the top. On the north side of this are Motur clays, while on the south side within a few yards, the green Talchir shales are seen. The quartzose rock is again seen in the Phopas and Deriakho rivers, but the fault is dying out here. To the east it is probably a prolongation of this fault, which disturbs the Sarni-Patakhera coal, and it may even be prolonged as far as the disturbance by Lenia though no trace of it could be found in the interval.

Faults older than trap outflow.

The trap is found covering the faults in places, as east of the Pench; to the south of the Bhandaria stream and the dyke north of Omerdo appears to pass across the fault. The faulting must therefore have been subsequent to the deposition of the Moturs but prior to the outpouring of the trap.

These faults where they bring the Moturs into contact with the Talchirs have an immense throw in some of the cases, as in the Pothia river it must be nearly or quite 1,000 and 1,500 feet, but this is merely local, as they die out rapidly to the east and west and the throw may appear greater than it really is through previous overlap.

§ 20.—*Quartz veins.*

Scattered through the area, but specially noticeable to the west, are numerous quartz veins which have been several times referred to. They have been formerly frequently noticed by those who have visited this basin. Mr. Medlicott has described them[1]:—

Description.

"The frequent occurrence of strong and continuous quartz-veins is perhaps the most peculiar feature of the southern zone of this rock-basin. Along the northern margin, where the contortion

[1] Rec. Geol. Surv. India, VIII, 3, 84.

of the strata is locally greater than here, I have not observed a single case of quartz-veining; and in other basins of these formations the thing is almost unknown. There is, however, one marked feature of these veins that has long been familiar to us in many parts of India in metamorphic and transition rocks—a peculiar pseudomorphic structure; thin shining plates of pearly white quartz, either in parallel arrangement or confusedly entangled, with empty interstices. I do not recollect noticing this form in vein-stones in other countries, but in India it seems to be nearly universal. The fine lines on these shining plates have suggested that they may be after micaceous iron. Stains of iron are common, but there are no signs of any other metal in these veins. There is often associated brecciated quartz."

Associated with faults.

As far as my observations go they often have no connection with faulting, in which cases the strata are little, if at all, disturbed in their neighbourhood; but as on the Lodadeo-Rawandeo ridge, at the Pothia and Saleye faults, they are certainly associated with the faults. There is no reason, however, to suppose that they owe their origin to the faulting except in so far as that would form numerous crevices and cracks favourable to the deposition of the silica. Their formation was long subsequent to the faulting and the resemblance of the plates of which they are so often composed, to the form assumed by micaceous iron, points to the conclusion that at one time the room now filled by the silica was formerly occupied by other minerals which were only subsequently slowly, but entirely, replaced by means of infiltration.

§ 21.—*Alluvial Deposits.*

In the river valleys there are alluvial deposits being formed along the banks of the rivers, consisting of the materials washed down from higher ground. One important constituent of this deposit is formed by trap in the form of rolled boulders derived from the surrounding trap hills, and which at times occur closely packed together with the sand and clay which alone are seen in other parts. These deposits, where they occur, hide a great portion of the older rocks.

CHAPTER III.

ECONOMICS.

§ 22.—*Coal.*

Prospects of working.

As regards the prospects of working the coal profitably in this field, it of course depends upon its quality, thickness, and position. The results of analyses of the coal from the outcrop are not favourable. I have reproduced here the assays given in Mr. Blanford's report, and added six more by Mr. T. R. Blyth of coals from localities that were not visited by Mr. Blanford.

Analyses of coal.

<table>
<tr><th rowspan="2">Locality.</th><th colspan="2">Volatile matter.</th><th rowspan="2">Fixed carbon.</th><th rowspan="2">Ash.</th><th rowspan="2">Remarks.</th></tr>
<tr><th>Moisture.</th><th>Exclusive of Moisture.</th></tr>
<tr><td>Chinda . . . . .</td><td colspan="2">16</td><td>61</td><td>23</td><td rowspan="3">Rec. G. S. I., XV, 136.</td></tr>
<tr><td>Barkoi . . . . .</td><td colspan="2">26</td><td>50·3</td><td>23·7</td></tr>
<tr><td>Bhutaria . . . . .</td><td colspan="2">26·5</td><td>49·3</td><td>24·2</td></tr>
<tr><td>Sirgora . . . . .</td><td colspan="2">28</td><td>61·6</td><td>10·4</td><td>From 30 feet below surface.</td></tr>
<tr><td>Takea river, near Datla (top of seam).</td><td>3·42</td><td>19·28</td><td>29·10</td><td>48·2</td><td>Does not cake. Ash, light gray.</td></tr>
<tr><td>Takea river, near Datla (5 feet below top of seam).</td><td>3·56</td><td>19·04</td><td>28·62</td><td>48·78</td><td>Does not cake. Ash, light gray.</td></tr>
<tr><td>Between Datla and Badee.</td><td>5·34</td><td>28·36</td><td>48·58</td><td>17·72</td><td>Does not cake, but sinters slightly. Ash light red.</td></tr>
<tr><td>Punnara . . . .</td><td>2·16</td><td>18·92</td><td>37·74</td><td>41·18</td><td>Does not cake, but sinters slightly. Ash red.</td></tr>
<tr><td>Tannia river . . .</td><td>2·10</td><td>26·38</td><td>54·34</td><td>17·18</td><td>Cakes, but not strongly. Ash red.</td></tr>
<tr><td>Sarni-Patakkra . .</td><td>4·00</td><td>26·02</td><td>49·46</td><td>20·52</td><td>Does not cake. Ash dark red.</td></tr>
</table>

With the exception of the coals from Sirgora and between Datla and Badee none of these results can in any way be termed favourable, but the specimens, with the exception of the one from Sirgora, were from the outcrop, and it is probable that the nature of the coal will improve to the dip; it might be desirable that borings should be carried out in order to test the quality of the coal lower down, and its thickness.

The following table gives the thickness of coal in the various outcrops. A portion of it is taken from the list at the end of Mr. Blanford's report.

The Roman numerals refer to those incorporated in the text.

List of outcrops of coal.

No.		Locality.	Thickness of seam.	Thickness of coal.	Average angle of dip.	Direction of dip.	Remarks.
			Ft. In.	Ft. In.			
Sirgora field.	I	Sirgora	above 4 9	above 4 9	5°	N	Not sunk through.
	II	Sirgora	3 0	3 0	5°	N	Not workable.
Barkoi field.	III	Chinda-Dighawani .	15 6	12 3	3°	N	
	IV	Seemkole stream by Rawanwara.	7 0	3 4	4°	N	Not workable.
	V	Rawanwara, Mr. Blanford's VI.	?	above 3 0	10°	N 20° W	Thickness not seen.
	VI	Dongur Parasia . .	?	1 0	8°	NW	Not workable.
	VII	Well ½ mile from D. Parasia.	?	4 6		?	Not seen.
	VIII	½ mile west of D. Parasia, Mr. Blanford's VII.	?	above 5 0	?	N	Thickness and dip not ascertained.
	IX	Ghogra between D. Parasia and Bhandaria, Mr. Blanford's VIII.	15 2	7 3	10°	N 10° W	
	X	Bhutaria-Bhandaria, Mr. Blanford's IX.	above 7 8	above 5 10	5°	S	Thickness not sunk through, much pyrites.
	XI	Barkoi	8 6	about 6 0	3°	SSW	Formerly worked.
	XII	Ekleyra	?	?	?	?	Doubtful.

No.		Locality.	Thickness of seam.	Thickness of coal.	Average angle of dip.	Direction of dip.	REMARKS.
Harai field	XIII	Harai	?	?	?	?	Probably shale.
Gajimdoh field	XIV	Gajimdoh . . .	5 0	5 0	40°	N 20° W	Not workable.
Hingladevi field.	XV	Hingladevi and Dhow .	? 6 0	? 5 3	slight	various	
	XVI	Pala Chourye . .	? 0 9	? 0 9	?	?	
Kanhan field.	XVII	Datla and Badee . .	above 9 8	above 9 8	10°	N	
	XVIII	Punnara	above 8 0	above 8 0	10°	N	
	XIX	Pooreena . . .	3 0	3 0	?	?	Not seen, reported by Major Ashburner.
	XX	Nundora . . .	3 0	3 0	10°	NE	Not workable.
	XXI	Damooa . . .	1 4	1 4	5°	N 20° W	Not of any large extent.
Tawa field.	XXII	Tamia river . . .	above 9 4	above 7 6	10°	SE	Locality very inaccessible.
	XXIII	Danwa	?	?	?	?	Small pocket.
	XXIV	Dodramou . . .	above 1 0	above 2 0	...	...	Pocket of coal.
	XXV	Bhogi Khapa . . .	2 0	2 0	5°	NW	Probably not workable.
	XXVI	Patakhera-Sarni . .	......	14 0	50°	W 20° S	Much disturbed.

Borings.

Mr. Blanford in his report strongly recommended borings at Sirgora, Bhutaria, Barkoi, Chinda, and Parasia.

In 1885, at the request of the Government of the Central Provinces, I recommended borings at Barkoi; a quarter of a mile south of the village at Sirgora; one by Major Ashburner's shaft; one in the low-lying ground to the east of the village; one near the well to the south of the banyan tree south of the larger portion of the village at Chinda-Dighawani; one on the small island in the Pench north of the coal out-

crop; one 250 yards to the east of this point, at Datla, half-way between the two outcrops; one to the east of this point at Panara, on the left bank of the river to the north of the outcrop.

In addition to these, it would be worth while to explore the Tamia seam by driving a short gallery on the coal, and the Patakhera Sarni seam by means of a boring to the dip. If the coal obtained in these borings were analysed, the results would give a far better idea of the quality of the coal than anything obtainable at the outcrop, and it would be seen whether the coal continued in force to the deep. The most favourable localities are Datla, Barkoi, and Chinda-Dighawani, but the others should not be neglected.

§ 23.—*Iron Ores.*

There is an absence of good iron ores in this field. The ferruginous shales, mentioned by Mr. Blanford at Sirgora, gave on analysis 47 per cent. of iron.

In the metamorphics, near Enkawari, the schists are somewhat ferruginous, but the iron does not extend for any distance.

§ 24.—*Limestone.*

Crystalline limestone in metamorphics.

In the metamorphic rocks between Bakur and Enkawari, and close to the boundary, there are several patches of crystalline limestone, which has been partially dissolved by the water of the streams passing over it, and redeposited further down in the form of travertine or tufa.

Tufaceous deposits.

Further to the east, where the streams fall a considerable height in passing from the metamorphics to the Talchirs, the tufa forms great blocks, filling up the bed of the streams at the bases of the waterfalls.

Motur nodules.

There is a large amount of limestone in the form of nodules in the Moturs, from which, by careful selection, a fair lime could probably be made. Kunkur also occurs in portions of the area.

§ 25.—*Clay.*

Inferior clay used.

Good serviceable clay seems to be scarce in this area, that which is used for making the very inferior tiles and bricks used by the villagers being obtained from the very impure alluvial deposits.

§ 26.—*Building Stones.*

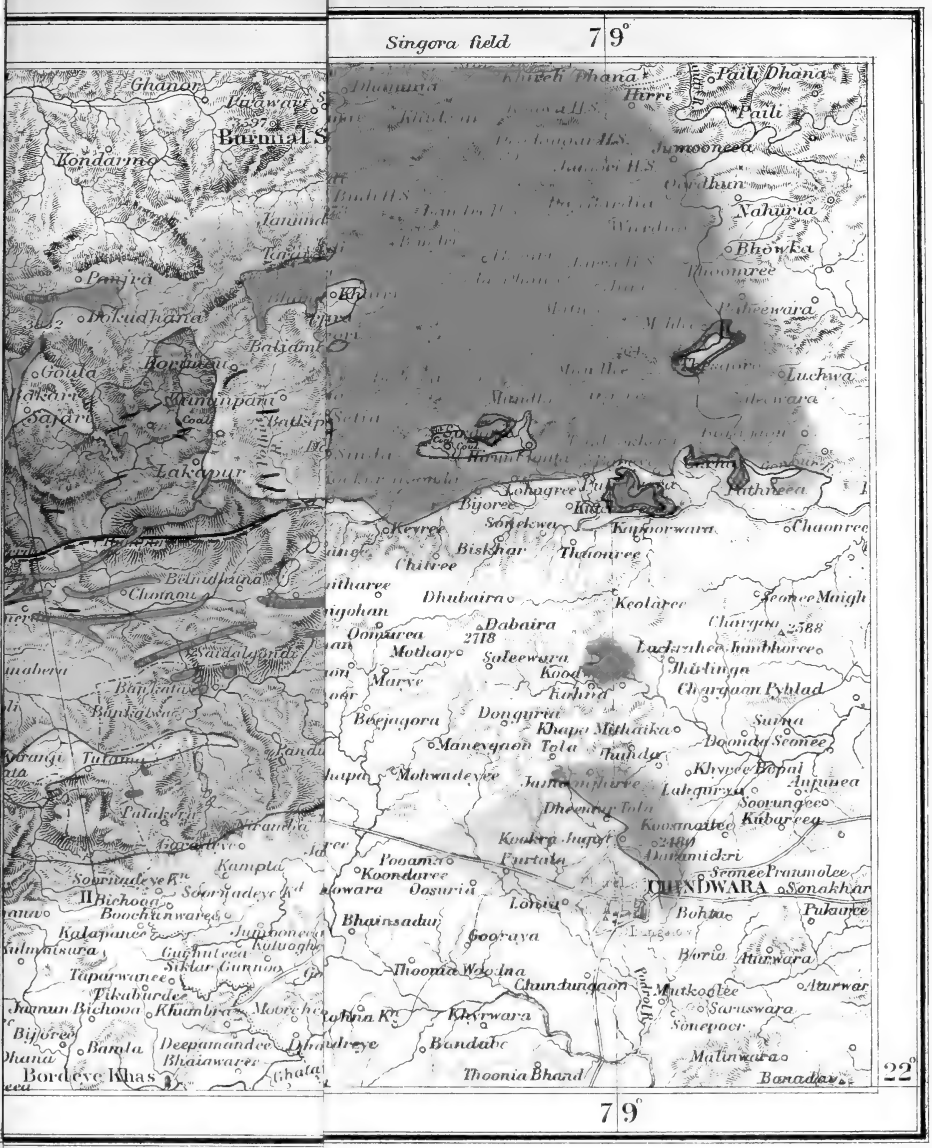
Good stones at Sirgora and Pathe.

At Sirgora the fine-grained white sandstone, quarried there, would make a good building stone; and near Pathe, in the neighbourhood of Shahpur, some of the Talchir sandstone was being quarried for building purposes.

Millstones.

Close by Panara, a sandstone is obtained which is largely used for hand-millstones. It is obtained from the Barakars close to the Motur boundary, and consists of a mass of coarse quartz sand, with only a small quantity of decomposed felspar, and harder than the usual Barakar sandstones, which may be due to some of the silica having been deposited in water and redeposited in such a manner as to form a cementing material.

Government of India Central Printing Office.—No. 44 D. G. Survey.—21-4-87.—400.



OF THE SATPU

...at the Litho. Office, Survey of India Department, Calcutta January 1887.

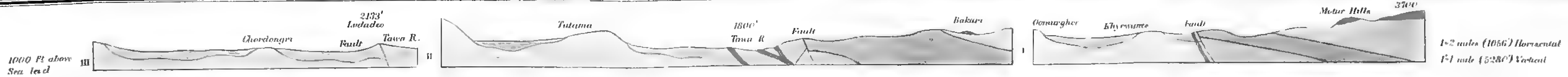
Scale 1 Inch = 4 Miles.

5

GONDWANA

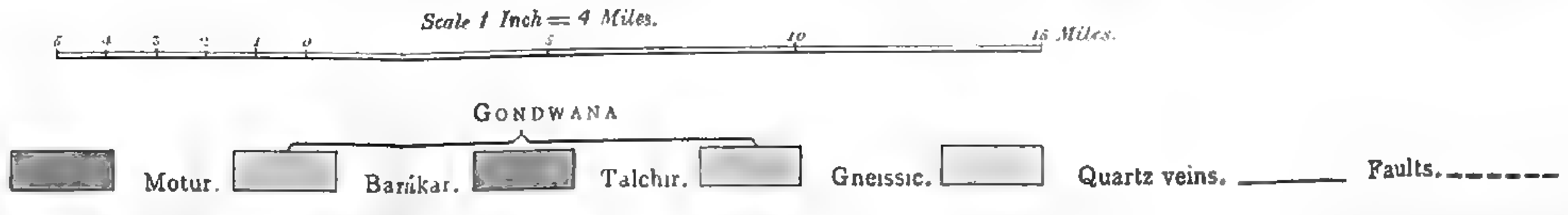
ákar.   Talchir.

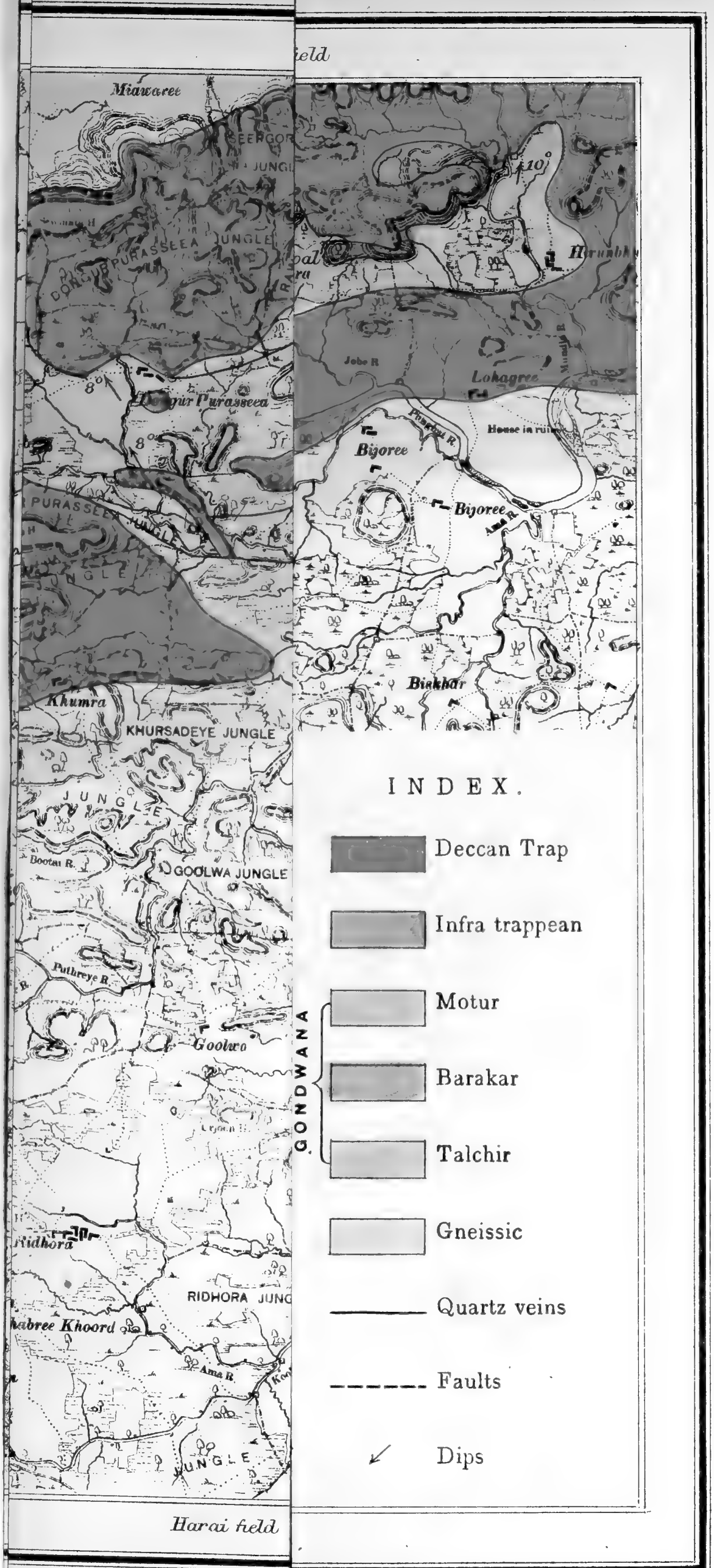
Taken from Sheets Nos. 53 S.E., 54 N.E., 71 S.W., & 72 N.W., of the Atlas of India.



SOUTHERN COAL-FIELDS OF THE SATPURA GONDWANA BASIN.

Printed at the Litho. Office Survey of India Department, Calcutta, January 1887





Harai field
Miawaree
DONGUR PURASSEEA JUNGLE
Dongur Purasseea
PURASSEEA JUNGLE
Jobe R.
Lohagree
Bijoree
House in ruins
Bijoree
Biakhar
Khumra
KHURSADEYE JUNGLE
JUNGLE
Bootai R.
GOOLWA JUNGLE
Puthreye R.
Goolwa
Ridhora
RIDHORA JUNG
Chabree Khoord
Ama R.
JUNGLE
INDEX.
Deccan Trap
Infra trappean
GONDWANA
Motur
Barakar
Talchir
Gneissic
Quartz veins
Faults
Dips

Extract from Sheet 4 of Chhindwara Revenue Survey

Photo Lithographed at the Survey of India Offices, Calcutta, February 1887

MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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MEMOIRS

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PHYSICAL GEOLOGY *of the* **SUB-HIMALAYA** *of* **GARHWÁL** *and* **KUMAUN,** *by* C. S. MIDDLEMISS, B.A. (Cantab.), *Geological Survey of India.*

CHAPTER I.

INTRODUCTORY.

Subject of this work.

The subject of this memoir is one which has already been treated of many years ago by Mr. Medlicott (late Director of the Geological Survey of India), in his description of the country between the Ganges and the Ravee.[1] The present work will have answered all anticipations if it come to be regarded as a continuation, along the mountain-foot of British Garhwál and Kumaun, of Mr. Medlicott's labours further north-west.

Geological structure of Sub-Himalayan zone simple compared with that of Himalayan, and treated separately.

During the four and a half working seasons which I have spent in the Himalaya, I have gradually been led to the conclusion that the great break between what is known as the Sub-Himalayan system, and the crystalline and metamorphic groups, is one which makes it eminently advisable to treat the two separately, in any finished written account of them. It has also become plain that if close work on the one-inch scale is to be done over the vast regions embraced by the outer and central Himalaya; and if that

[1] Mem. III, G. S. I.

work is to be brought into a form suitable to the requirements of modern scientific thought; it will take a considerable time to collect the material in the field, and to work it up into a homogeneous whole. Such papers on the subject as I have hitherto contributed to the "Records" of the Geological Survey deal with isolated areas; and it will only be by continually adding to these that the way can be prepared for a thorough digest of the whole region. In the meantime, it seemed to me that the comparatively simple Sub-Himalayan zone need not wait until all the difficulties which surround the older hills like a great cloud were dissipated. Moreover, in any case, it would have seemed advisable to me to describe the Sub-Himalayan zone first, whether the whole were combined in one book or not; because, just as the physical aspect of these hills suggests a stepping-stone from the plains to the lower parts of the main range, so does their geology prepare us, or carry us, step by step, to an understanding of the great geological problems sealed up in those mountain strongholds.

Previous writers.

In the year 1864 Mr. Medlicott produced his memoir "On the Geological Structure and Relations of the Southern Portion of the Himalayan Range between the Rivers Ganges and Ravee." In that book he devoted most space to the Sub-Himalayan zone; supplementing the palæontological researches of Cautley, Falconer, and D'Archiac and Haime, by putting the lithology and stratigraphy of the investigated area on a sound basis of observed fact. Besides this, he was the first to attempt a classification of the older Himalayan rocks. Finally, he considered the whole of the Himalayan and Sub-Himalayan groups, individually and together, with regard to the *rôle* they have played in the general structure and history of the mountain-range. That book, therefore, will very naturally form a constant subject of reference; more so, indeed, than the works and papers of other writers on adjoining areas,—*e.g.* Stoliczka, Lydekker, W. T. Blanford, R. D. Oldham, McMahon. As for the authors, Herbert and Strachey, who came before Medlicott, their results have been criticised by the latter in his quoted memoir, and so need not be referred to again.

New features in this work due to better maps.

As stated above, the present work aims at being an extension in a south-easterly direction of the geological operations described in that memoir. Owing to the possession of better maps, it has been possible to accomplish this in more detail than was possible in 1864. Much of the ground herein covered has been topographically surveyed by the Forest Survey, on a scale of 4 inches to the mile. These maps leave nothing to be desired, and are invaluable in a country of dense jungle and few landmarks, such as the Sub-Himalayan tract. Wherever I have been able to use them, I have been constantly reminded of the debt of obligation the geologist owes to the conscientious map-maker. The 1-inch maps of the Trigonometrical Survey are available for the whole of Garhwál and Kumaun; and I have worked with them in the field, wherever the larger ones were not yet published. For the coloured maps accompanying this work, I have been compelled to be content with the ¼ inch atlas sheets; which are reduced from the 1-inch maps. Though very good as a whole, their accuracy is not to be depended upon in the intricate wooded districts. The chief features of novelty, therefore, that I would claim for this book, in advance of Mr. Medlicott's, are connected with the closer and more accurate delineation of the geology rendered possible by these better maps; together with such amplifications and modifications of that author's theory of the Sub-Himalaya as have been brought to light by the foregoing advantages in a tract of country naturally endowed with clear and convincing sections.

Popular misconceptions as to the upheaval of the Himalaya.

Even without any new features whatever, I should have very little hesitation in placing the results of my work before the public, inasmuch as there is perhaps no geological structure so greatly misunderstood by many English geologists as the Himalaya. In the face of Mr. Medlicott's writings, it is not easy to understand why this is so; and I can only partially account for it by the consideration that, like Darwin, Mr. Medlicott is a difficult writer, who requires following

through an argument with the closest attention and often reading several times before his full meaning is grasped.

As an instance of the misconceptions prevailing, Dr. Geikie[1] writes, speaking of the Siwaliks, or younger tertiaries: "They have "been involved in the last colossal movements whereby the Himalaya "have been upheaved;" whereas Mr. Medlicott, in enumerating the principal conclusions to which he was led by the study of the Himalaya, writes[2] "the Himalayan mountain-area was defined before "the deposition of the Sabathu nummulitic rocks" [or older Tertiaries]. It is true that in later remarks made in the *Manual of the Geology of India*,[3] he has qualified this statement to a certain extent by urging that all special Himalayan disturbance was altogether post-eocene [post-nummulitic]; but he again qualifies this, as regards an earlier pre-nummulitic state of Himalayan elevation, which he likens to a simple protuberance (*bossellement*), or warp, and which he declares to have been considerable, though probably unplicated. The first of these qualifications, however,—namely, that all special Himalayan disturbance was altogether post-eocene,—is misleading if read loosely. The reader is apt to go away with the belief that Mr. Medlicott thereby meant that the Himalayan range, as a great mountain barrier, was undeveloped at that time: he used the words special Himalayan *disturbance;* but apparently he has been understood by Dr. Geikie to mean special Himalayan *upheaval*—a very different thing. Unfortunately, in making that statement, the former author was trusting largely to the section across the Lapri and Sangar-Marg ridges in the Jamu area[4]; where a manifest uniformity in lie between the nummulitics and the Great Limestone (the probable equivalent of the Król limestone) gave a strong presumption in favour of the belief that the Himalayan rocks were undisturbed before the deposition of the nummulitics. But it is

[1] Text-book of Geology, p. 879, 1st edn., 1882. [3] P. 569.

[2] Mem. G. S. I., Vol. III, p. 174.

[4] He also mentions the section of the Sabathu rocks in the Simla area; but the disturbances of all the strata there are so extreme that I cannot regard the evidence of conformability as sufficiently conclusive.

evident that that belief depends on the assimilation of the Great Limestone as conformable with the still older rocks,—namely, the palæozoic slates and schists, which occupy much of the higher Himalayan range. Herein, I shall subsequently show reason for differing from Mr. Medlicott: it will be made clear that the nummulitics, though in many places lying in the same state of disturbance as rocks of probably mesozoic age, which in turn are equally disturbed, with a great or massive limestone formation coming beneath them, are probably merely the uppermost beds of a zone of formations which must be regarded as young, compared with most of the great Himalayan range itself. That is to say, I shall introduce behind the Siwalik and Nahan rocks (upper tertiary) a disturbance zone, composed in ascending order of massive limestone, Tál (mesozoic), and nummulitics, which bear the same relation to the older slates and schists that the Siwaliks bear to them. The matter, in a word, is this: Mr. Medlicott supposed the Great Limestone of the Jamu area to be palæozoic; and therefore the nummulitics, which were thrown into folds with it, give a tertiary date to the disturbance of the whole *palæozoic* rocks of the Himalaya. I myself (in agreement with Mr. Lydekker) by showing the massive limestone to be more probably of mesozoic age, and divided sharply from the still older slates and schists, merely give a post-nummulitic date to the disturbance of this zone of *mesozoic* age; leaving the question of the still older palæozoic rocks very much where it was before.[1]

The conclusions to which I am led by independent exploration are in entire agreement with Mr. Medlicott's original statement in the memoir, save that I would go further. I believe that, if we could have been present in Siwalik times,—nay, even in Nahan or nummulitic times,—we should have seen the Himalayan range in all its might standing up very much as it does now.

[1] From one remark in his memoir Mr. Medlicott would seem to have once leaned towards this view. At page 170 he says: "From this point of view there are many reasons for associating the calcareo-shaly band, which I have described as the Król group, with the younger rather than with the older strata."

A similar misconception is to be found in Mr. Mellard Reade's "Origin of Mountain Ranges," a more recent publication. He says:[1] "The Himalaya, the Andes, the Alps, and the mountains of the Cau-"casus have been to the larger extent upheaved in tertiary times;" and further on,[2] referring to India, he makes the startling announcement that "The tertiary [system] alone, measuring 30,000 feet, has "been upheaved and carved by denudation into the greatest mountain "system of the globe,—the Himalaya." To say that the mountains of Wales and the Lake District were carved out of post-tertiary glacial deposits, would have a relatively greater basis of credibility than the statement in question; for those glacial and palæozoic rocks are less unequal, in height and ratio of distribution, than are the tertiary and the Himalayan rocks in India. I shall have further remarks to make on this head in the body of the work.

An impartial view solicited.

These instances show how hard it is to break down an ancient prejudice. For a long time, the fact that the youngest Siwalik conglomerates seemed to share in the same folds which the oldest Himalayan rocks have shared in, convinced the geological world that the date of the upheaval of the whole Himalayan range was quite modern; and this belief, once engendered, has steadily gone on propagating itself in spite of later research. If, in the following pages, I can do something towards bringing about a more reasonable and impartial view of the case, I shall be content.

The material for this memoir has been collected mainly during the months of January, February, and March 1887; January, February, March, and April 1888; and January, February, and March 1889. As having had something to do with preparing the way for a geological exploration of this region, I may mention that, on first joining the Survey at the close of 1883, I accompanied Mr. R. D. Oldham over portions of the Siwalik range and the Dehra Dún, by which means I was able to see a part of the area described by Mr. Medlicott.

[1] Chap. V, page 29.
[2] P. 73.

CHAPTER II.

SCENERY AND SUPERFICIAL ASPECTS OF THE COUNTRY; ITS FLORA AND FAUNA.

Definition of the Sub-Himalayan zone.

Between the Ganges at Hardwár, and the western frontier of Nepál, stretches the tract of country to be described in the sequel. It is some 130 miles long, and varies from 6 to 14 miles in width. It is composed of low hills and shallow valleys, and rises sometimes abruptly and sometimes gradually, from the great alluvial plains on the south; and merges more or less imperceptibly on the north into the elevated country of the outer Himalaya. Geologically, it is known as the Sub-Himalayan zone, being composed of tertiary rocks; and is continuous with that of the same age and formation trending in the opposite direction from Hardwár, comprehended in Mr. Medlicott's memoir. Its surface features are very characteristic of the zone of which it is a continuation,—that is to say, the hills are low and flowing, they seldom rise to any great height above 3,000 feet, and they are distinguished by the presence of several beautiful, flat, longitudinal valleys, known as dúns, some of which bear a strong resemblance on a small scale to the Dehra Dún north-west of Hardwár.

Its magnificent forest scenery compared with the higher Himalaya.

On first visiting this country one is much struck by the beauty and luxuriance of the forest scenery. It is true, there are none of those sublime sights which one meets with in the higher Himalaya. It is impossible from any one height to take an extensive survey over range beyond range of purple peaks, or across the harsher black and white pinnacles of the snowy range: the view is much more confined, and the eye bewildered by the labyrinth of small wooded knolls. But there is a softer beauty of a different order to be found here, for which the traveller in the higher hills may seek in vain. The flora is sub-tropical, and gives an aspect of richness and bursting vegetable life to the scene, as well as naturally increasing its brilliance by the vivid greens. As is characteristic of these hot and

moist regions, there are no flowers, except a few large ones flaming here and there. Nature is too full of life to need such artificial aids to fertilization.

It is rather the forms of the forest elements which give the charm. A thick grove of Sál trees (*Shorea robusta*), covering a flat chaor,[1] is a magnificent sight in itself, even though its primeval maze of climbers, &c., has fallen before the conserving care of the Forest Department. But when broken country is reached,—when the flat plateau gives way to the steep scarp, or steady slope down to the river bed,—the varying conditions offer many other trees a home, whose striking forms have a strong individuality of their own, such as the Bamboo, the Cotton-tree (*Bombax malabaricum*), the red-tinted Bákli (*Anogeissus latifolia*), and the great thorny jungles (*Acacia*) of the alluvial flats and dry river-beds. They harmonise well with the ever-changing panorama of winding river-bed, of naked ochre-tinted cliffs and deep pools, of softly-swelling slopes, or of jagged mural scarps rising one behind the other. Sometimes in wandering through this region a deep gorge is reached with bare rock below and festoons of tangled creepers and shrubs above, shutting out the sky. And when, after leaving this array of miniature crags, peaks, and precipices, the dún itself is entered, the sight is rested as it falls on the gently undulating plain, which, expanding in all directions in a sea of Sál forest, dies away at its margin into a thousand slightly-inclined slopes, ultimately steepening and ending either in the serrated peaks of the Siwalik ridge to the south, or in the mountain-foot of the greater Himalaya to the north.

Climate: Government forest.

The Sub-Himalayan zone is visited by a heavy monsoon, during June, July, and August, and has an annual rainfall exceeding 60 inches; it therefore forms part of a climatic zone which is one with that of Bengal and the coast of Burma. In consequence of these favourable conditions, it supports dense forests, rich in a few species of very valuable trees. Nearly all

[1] A *chaor* is a level or gently sloping bit of ground, generally elevated above the neighbouring drainage lines.

the Sub-Himalayan forests are under Government, and yield a large revenue to the State. They are managed directly by the Forest Department, which looks after the maintenance and working of them.

The Sál tree.

The principal tree which thrives in this area is the Sál (*Shorea robusta*). It is a large tree, with broad, shining leaves, and allied to the Copal (*Vateria indica*) and the Lac-tree (*Shorea laccifera*) of West India and Mysore, respectively. It is also of the same family as the Wood-oil trees (*Dipterocarpus*) of Burma, and the Camphor-tree of Sumatra and Borneo. It ranges everywhere from the plains immediately at the foot of the hills up to heights averaging 3,000 feet. It sometimes forms almost pure forests, which grow with great vigour on the light sandy soils of these hills; but more often it is mixed with several other less valuable trees. On wide open chaors, either flat or gently sloping, but still out of reach of the river floods, it flourishes; but it shuns clayey ill-drained soils and steep country, and at great heights it becomes useless as timber. The wood of the Sál is very durable, though taking a long time to season, and apt to split and warp. It is largely used for building purposes and for railway sleepers. From a commercial point of view, it is *the* useful tree of the Sub-Himalayan zone, and supplies the place of the Teak of Burma and the Deodar of the higher Himalaya.

The Sissoo and the Khair.

Just as the dark shining green of the Sál is the most conspicuous object on the flatter slopes and chaors, so the dry river-beds, wherever they possess low banks and islands composed of hardly-reclaimed recent gravel and alluvium, give us the well-known forms of the Sissoo or Shisham (*Dalbergia Sissoo*) and the thorny Khair (*Acacia Catechu*). Unlike the Sál, which is never quite leafless, these trees are bare and brown during the cold-weather months, causing the white stony stream-beds to have a death-like, forsaken appearance. But in March and April they all burst into leaf, and light up the islands and banks with a pale-green tint, which contrasts strongly with the sombre colour of the dark Sál forest above and with the bright-red flowers of the Dhák-

tree (*Butea frondosa*), which is then in bloom. The wood of the Sissoo is valuable for its strength and elasticity, and is used for carriages, camel-saddles, and agricultural implements. It is also a beautiful furniture wood. The Khair is a very hard wood, and was formerly used for sugar mills, but is now superseded by iron in this respect. It is principally useful for making catechu, which is employed in dyeing and tanning, and also medicinally as an astringent. In ravines and damp places among the Sál covered hills grow the Soanjna (*Moringa pterygosperma*) and the Jáman (*Eugenia jambolana*).

The Bamboo.

Another special feature of the Sub-Himalayan zone is the Bamboo (*Dendrocalamus strictus*), which takes the place of *Bambusa* of South India. Its feathery foliage adds a graceful appearance to the drier and more stony low ground and hollows at the foot of the hills, where it is generally to be met with, though it also extends up the hill-slopes themselves, preferring those with a southern aspect. Its uses are proverbial, and next to the Sál tree it is the most important product of these forests. It is easily cut and carried away, needing but an axe to shape it. The sale of it brings a large revenue to the Forest Department: the average annual amount realised during the years 1881-1886, in the Ganges Division of forests alone, was R32,984.[1]

Other useful woods.

There are a number of other forest trees, which are found in certain places amongst the Sál, and are worth mentioning here as being useful woods. The principal are Sain (*Terminalia tomentosa*), which may be considered as the complement of Sál, since it favours a clayey soil, whilst the latter will not thrive on a stiff soil. It is largely used as fuel, for building purposes, for making potash, and the leaves are eaten by the tussah silkworm. Gosam or Kusam (*Schleichera trijuga*), which also affects clayey soil, and is remarkable for its hardness, and is made into sugar-crushers, rollers, harrow-teeth, ploughs, &c. Hair (*Termi-*

1 See Working-Plan of Ganges Working Circle (Forests), p. 31, by N. Hearle, Deputy Conservator of Forests.

nalia chebula), the wood of which is valuable, and the dried fruits are the Black myrobalans of commerce; Bákli (*Anogeissus latifolia*) abundant in hilly parts and nearly always restricted to southern slopes. On account of its hardness it is extensively used for furniture, agricultural implements, ship-building, and it is also used as fuel. Sándan (*Ougeinia dalbergioides*), abundant on hot, dry slopes, and ascending to 5,000 feet in some places; a useful wood of the same character as the last. Tendu or the Ebony tree (*Diospyros*), found on hilly exposed tracts; a beautiful furniture wood. Toon (*Cedrela Toona*), rare, in damp shady valleys only. This is also a highly-prized furniture wood; it is also lopped for cattle; the bark is a powerful astringent, and from the flowers a yellowish dye is made. Riuna (*Mallotus phillipinensis*), a large shrub with a deep red fruit, the size of a holly berry, is a common sight in these hills. The red dust covering the fruit is used principally as a dye.

Among these trees in the natural forest, the climbers Máljan (*Bauhinia Vahlii*) and Gauj (*Milletia auriculata*) are frequently conspicuous; but as they do much damage, by smothering the trees to which they cling, they are destroyed in the reserved parts.

There is perhaps no more characteristic feature among these forests than that afforded by the Haldu, the Pipal, and the Semal. The two former generally grow solitarily or in small clumps, in low flat country, by the banks of streams or at the foot of the hills. The Haldu (*Adina cordifolia*) is a useful shade tree, and is also of value for its wood. It is common in the Bhábar country, and gives the name to the villages Haldwáni, Haldukháta, Halduwála, &c. This tree is said by Mr. Hearle to be dying out in the Ganges Division of forests, as no young trees are to be found thriving. Further east, however, this does not seem to be the case. The Pipal (*Ficus religiosa* and *F. cordifolia*), being sacred to the Hindus, is planted by them near villages and shrines, though it also grows wild. Both the last two trees form magnificent spectacles when full-grown, as they attain to the great size of 80 to 90 feet. The ground near one is commonly chosen as a camping-ground, for the sake of the shelter it affords. Another

large tree is the Semal (*Bombax malabaricum*), or cotton tree, which rises to the height of 150 feet, with a tall, straight, buttressed stem. It is a marked feature in the landscape in the cold weather, when it is leafless, but covered with large scarlet flowers. The wood, on account of its lightness and resistance to water, is used for boats, well-curbs, &c. The cotton is gathered from the unripe fruit, and used to stuff pillows, &c.

The wild mango (*Mangifera indica*), though not as marked a feature as the cultivated variety of the plains, is however found in a few places. It is chiefly of value for the fruit it yields under cultivation.

An undergrowth of the common *Adatoda justitia*, of *Zizyphus* of several species, and of many other shrubs covers much of the low country, along with the Munj or Elephant-grass (*Saccharum sara*), which grows to great heights; while Bábar-grass (*Spodiopogon angustifolia* and *Eriophorum comosum*) is found on the hillsides and is largely employed in making cordage and paper.

The preservation in a luxurious condition of these forests entails a great deal of labour on the part of the Forest Department. The great enemy dreaded during the hot months is fire, when the long dry grass and Sál leaves, and the dead and small timber, is such as to enable it to spread with extreme rapidity, destroying seeds and seedlings, laying bare the ground, and interfering with the natural decay of leaves, &c., into the nitrates which manure the soil. The rapid production of ash by burning leaves it in a thick superficial layer, which is carried away by the first rain, instead of fertilising the ground *in situ*, besides exposing the soil to the direct rays of the sun. Wild elephants are a great source of loss to the bamboos and young Sál, of which they are inordinately fond. There are also numerous insect-pests, such as the formidable stag beetle and the white-ant,[1] against which little can be done, save the preservation of the smaller birds by reducing the numbers of the birds of prey.

[1] It is a question, however, whether the function of the white-ant in turning up the soil is not, in some measure, a compensation.

What is the relation, if any, between the geological formation of the Sub-Himalayan zone and the covering of forests? This is a difficult question to answer directly, because so many secondary results follow on a certain rock-structure, that it is often more probable that the favoured trees depend rather on these secondary results or on the aspect of the hill slopes than on the primary structural causes. A comparison of the stock maps (which have been kindly lent me by the Forest Department) with my own geological maps, is to a large extent disappointing; the stratigraphical zones do not, at the first blush, seem to show much resemblance to the different stock areas. Large portions of the Pátli dún, for instance, are composed of Siwalik conglomerate, and these are covered with a growth of fine young Sál. But the Chokhamb and Kotri dúns, where the conglomerate is absent, have also many fine Sál forests. So that the particular petrological constitution of any part of the sub-Himalaya, varying but slightly in its chemical elements and state of solidity from its neighouring zones of tertiary age, does not seem to be a very important factor in determining the nature of the stock. In some measure this is what we should expect, for, as will be seen in the following chapter, the several rock stages of the Sub-Himalayan formations being very much alike in their general facies and in the ultimate material into which they can be reduced, produce, of necessity, a very similar soil under like conditions of drainage and aspect. The following generalizations seem to hold to a certain extent; though numberless modifications, dependent on those natural and more superficial causes which I need not stop to mention, have great prominence:—

(1) The northern limit of the Tertiary zone is practically the limit of the Sál tree, and therefore of the reserved forests of this region. This geological boundary is a very important and marked one, and seems to have a real and direct effect on the prevailing forest species.

(2) The Middle Siwalik sand-rock[1] generally forms low undulat-

[1] See Chap. III,—Petrology.

ing country, and towards the plains supports a miscellaneous jungle. A good example of this is seen between Rámnagar and Kálagarh, on the plainward parts of the hills.

(3) Wherever the dip of the strata is low, 10° to 30°, and down hill (which generally coincides with a northern aspect), the Sál, tree has flourished far above any other tree. Obviously, however, the coincidence referred to in brackets may, after all, be the vital reason.

(4) All escarpments and sloping country, with dips towards the hill, support a miscellaneous jungle. This may be due, however, to secondary causes, arising partly from the more varied secondary slopes and ridges into which such a structure weathers, and partly because of their facing south.

Thus, in a section such as on the margin, we should find the forest disposed as marked :—

(5) All surface-gravels, dry river-beds, and shingle islands, which are constantly liable to change, to being washed away and re-made lower down, only support the Khair, the Sissoo or Shisham, and sometimes bamboos.

Rivers.

The country is well watered by four large rivers, the Ganges, the Rámganga, the Kosi, and the Sárda; and by numerous smaller rivers and streams of some importance. The Rámganga and the Kosi both rise in the higher Himalayan zone, but their waters are not fed by perennial snow.

The Ganges, and the Sárda, on the other hand, have their several affluents originating in the great central chain of the Himalaya, and melting glaciers and snow-fields go to form their icy streams. Whilst these two large rivers cut straight through the Sub-Himalayan zone without swerving, the two former rivers each take a con siderable turn on entering it,—the Kosi very notably between Okaldhúnga and Mohán, and the Rámganga in its traverse along the Pátli dún. The distinction in this respect seems to be due partly to the greater strength of the current in the case of the Ganges, which enabled it to cut through the advancing flexure wave of the Siwalik rocks, whilst, of the other two rivers, the Kosi was successfully turned for some way by a similar flexure in the Nahan rocks, and the Rámganga by one in the Siwaliks; partly the difference may be due to a fault along the Ganges where it escapes through the Sub-Himalayan range—a fault due to great lateral wrenching of the strata as they inbay in a direction up the present Ganges bed. The Gola, Nandhaur, and Ladhia rivers come next in importance; and they all show at some point of their course in the Sub-Himalaya a longitudinal diversion of their waters following the axes of folds. Of the streams which rise in the Sub-Himalayan zone itself, the Sona and the Peláni (Paláine) both fall into the Rámganga. They and the Kalaunia are the most characteristic of the younger rivers of this zone, which are more than mere torrents. Their waters are pure and sweet; and they meander with much twisting and recurving upon themselves, in a way quite unlike the streams and rivers of the higher Himalaya, which run a more direct course. Many of these Sub-Himalayan streams carry down with them a meagre quantity of gold, which is washed in a small way during the rains.

The periodical monsoon to which India is subject necessarily causes a great and rapid increase in the volume of water carried down by these rivers at that time of the year. Hence what is but a mere trickle of water amongst vast beds of shingle during the cold weather, becomes a broad and mighty torrent when the rains have fairly set in. Snow-fed rivers, such as the Ganges and the Sárda, in addition have their waters very much discoloured by the melting of the glaciers as

soon as the hot months commence, and long before such rivers as the Kosi and Rámganga become tinged with mud from the monsoon which follows.

Fauna.

A tropical country, possessed of all these advantages of forest and flood, of secluded valleys and hidden gorges, cannot but be rich in animal life, and especially in the larger mammalia. The Sub-Himalayan zone is verily a paradise for the sportsman. There is every style of country in miniature; abundant cover, afforded by the system of reserving the forests; and every other inducement that would tempt the largest and fiercest of wild animals to make it their home. In addition, it is a sort of meeting-ground for the fauna of the hills and the plains; which, by its variety of surface features, can accommodate both. It is of interest to geologists and naturalists, as bearing on the distribution of animals in time and space, to reflect that, during the ages when the Sub-Himalayan rocks were deposited, there flourished a large and fierce group of mammalia, whole families and genera of which are now extinct; and that this portion of the earth still affords refuge for the few representative descendants of those mammalia, which exist at the present day.

A brief epitome of the more important and larger animals must here suffice. The Asiatic Elephant (*Euelephas indicus*) is thoroughly at home among the Siwalik hills, where food and seclusion are at his command. As shooting this animal is forbidden, except in certain cases, the reserved forests have become a sort of elephant preserve, which is drawn upon every few years, when fresh supplies of tame elephants are wanted by Government. They are caught by being driven into deep sóts (stream beds), having only one outlet. If they offer resistance, they are reduced to a state of submission by special fighting elephants, and then secured by ropes in the ordinary way. Of the carnivora, the Tiger (*Felis tigris*) regularly inhabits the flatter portions of the country, especially the dúns and the deep sóts which run up into the hills from the dúns. It is also very numerous just at the foot of the Siwalik hills and downwards to the Terai. The Panther and Leopard (*Felis pardus*) occupy the hillsides, and prey upon

smaller animals ; but they are seldom found in the dúns, doubtless because they recognise that the tiger has the monopoly of the flatter parts. The Wild Dog (*Cuon rutilans*) scours much of this zone in packs, slaying large numbers of deer, especially females and young ones. The Indian Black Bear, or Sloth Bear (*Ursus labiatus*) is common. Being an inhabitant of the plains it does not ascend very high. The Himalayan Black Bear (*Ursus tibetanus*) is often to be met with in these lower hills, though its more natural country is higher up in the Himalaya, in the region of the oak trees upon which it feeds. The Indian Wild Boar (*Sus indicus*) is fairly numerous. The Nilgao (*Portax pictus*), or blue bull, is only very occasionally met with in the flatter dúns; its natural home being below in the Bhábar country and the Terai. None of the antelopes or gazelles, except the four-horned antelope (*Tetraceros quadricornis*) are to be found in this zone. They need the unfettered freedom of the wide plains to live naturally. The genus *Capra* belongs entirely to the higher parts near the snows, and to Tibet. The Serow (*Nemorhœdus bubalinus*) is, however, a common sight on the bare and steeper scarps and precipices of the Sub-Himalayan zone, whilst the Gooral (*Nemorhœdus goral*) is extremely common in similar localities. Of the family *cervidae* this zone has a lavish display so far as number go. The most plentiful species is the spotted deer (*Cervus axis*) which inhabits all the dúns, the country at the foot of the hills and the flatter chaors. It loves to bury itself in the deep sál forests during the hot part of the day, and to wander in herds among the long grass of the plains and dúns at early morning and evening. The Sámbar, or Jerao (*Cervus aristotelis*), on the other hand, frequents the more hilly country, although it is a larger animal than the spotted deer. It ranges for some distance into the higher Himalaya, preferring steep ridges and deep wooded glens to the more open country, except in the cold weather, when it may be found in the dúns and Bhábar country. Along with it, in similar situations, is to be found the Barking-deer (*Cervulus muntjac*), a small red deer. Another small animal, the Hog-deer (*Cervus porcinus*) is a common accompaniment to most of

the marshy stream-beds, whose waters flow longitudinally with the geological strike of the country.

The larger rivers of this zone are full of fish; the chief of which are the Máhseer or Indian Carp (*Barbus tor)*, and the Indian Trout (*Barilius bola*). A species of *Labeo* is very common in the Peḷáni R. There are also fresh-water Tortoises, Crocodiles, and Otters in the Ganges and Rámganga.

Malaria.

Although nature has fitted out these jungles with every requisite for the brute creation, the human inhabitants are not so well off. The unsurpassed loveliness of the country, its crystal waters and brilliant skies, would lead a casual traveller in the cold weather to imagine that no more desirable spot to dwell in could be found. And this is true, in a large measure, for the winter months of the year. But in the hot and rainy seasons, especially during May, June, July and August, the climate is one of the most deadly in India. Malaria then stalks through these jungles, and a native's life is not worth much (I am told) after three years' experience in them. In this respect it is said to contrast unfavourably even with Assam.

CHAPTER III.

PETROLOGY.

Classification and scope.

It will be well, at the outset of this chapter, to give the classification of the Sub-Himalayan system[1] inaugurated by Mr. Medlicott; and to indicate, by a parallel table, the formations which are represented in this district. The following is Mr. Medlicott's classification :—

SUB-HIMALAYAN SYSTEM.	Siwalik Series	Upper.
		Middle.
		Lower (Nahan).
	Sirmúr Series	Upper (Kasauli).
		Middle (Dagshai).
		Lower (Sabáthu: nummulitic).

[1] So far as possible I have made use of the stratigraphical and chronological terms recommended at the Bologna International Geological Congress. Thus, in descending order of magnitude—

Stage = Age.	System = Period.
Series = Epoch.	Group = Era.

The Upper, and a portion of the Middle Sirmúrs, are not represented in this district; we therefore have—

SUB-HIMALAYAN SYSTEM.	Siwalik Series . .	Upper. Middle. Lower (Nahan).
	Sirmúr Series . .	Middle (Dagshai) in part. Lower (Sabáthu: nummulitic).

As equivalent terms, I shall make use of the following, which depend for their nomenclature on the character of the composing rock:—

Siwalik conglomerate	=	U. Siwalik.
Sand-rock stage	=	M. Siwalik.
Nahan sandstone	=	L. Siwalik.
Nummulitics	=	M. Sirmúr (in part). L. Sirmúr.

It will be seen from this that the geological succession is a simple one. It is even simpler in the *de facto* Sub-Himalayan zone, as defined by Mr. Medlicott; for, as explained by that author, the nummulitics lie in a zone among older Himalayan rocks, some distance above the main boundary fault which divides the Sub-Himalayan from the Himalayan country. For several reasons, therefore, I shall only describe in detail the rock series as found occurring actually in the Sub-Himalayan zone. I have been led to do this partly from the fact that the large-scale Forest maps do not, in the majority of cases, extend beyond the Sub-Himalayan zone; and partly because the nummulitics, in this part of the country, are in the form of a very thin band, and appear so constantly in a regular succession upon a set of mesozoic formations, that it would be absurd to describe the one without the others. The nummulitics will, therefore, be left for subsequent delineation along with the Himalayan formations. This decision will not interfere with my taking any one individual section, such as that along the Peláni R., and discussing it, even as far as the metamorphic rocks, for the purpose of illustrating the relations of the Sub-Himalayan to the older rocks. Such sections will, however, merely be illustrative, and not exhaustive.

The description of the individual formations of the Sub-Himalayan tract, from a petrological point of view, is sufficiently easy. There

is a certain sequence in these Upper Tertiary strata, never departed from, without a fault, or thrust-plane, being evident. But the several members of the sequence, though of minor interest in themselves, become absorbing when regarded as the parts of a puzzle; which, if put together rightly, will initiate us in the mysterious workings of those elevatory powers, whereby band after band of rocks have been won from the oblivion of the plains and added to the achievements of the Himalaya; or they may be looked upon as an alphabet, or key, that will enable us to read this last volume of geological history, which, written in a strange language, now lies open before us.

Recent formations.

The superficial deposits of Recent age may be disposed of in a word or two. They consist of banks of coarse gravel and torrent-boulders, generally mixed with ferruginous sand or clay, which line the margins of many of the larger streams and rivers, and cover great portions of the dúns and level chaors. In one or two localities about Chúna Khán and Madan Bhíl, and in the more eastern portions of the Kotah dún, where the streams carry much lime in solution, there are some beds of very pure calcareous tufa, interstratified with gravel banks and sandy clays. The streams which emerge from the Kotah dún, at its eastern limit, cut through escarpments of the Siwalik conglomerate, often by a series of falls, or steps of calcareous tufa, one of which at Madan Bhíl is about 50 feet high. The stream-beds are sometimes filled with huge weathered blocks of this tufa, of pale grey or dirty-white colour, and of an appearance akin to that of scoriaceous lava. Impressions of land-shells and plants are frequently found in them. In the Nehál Nadi,[1] south of Naini Tál, there are also superficial deposits of gypsum[2] of considerable extent. Re-made beds of the Nahan shales, sloping down the sides of the gorge a little south of the old Nehálpur bridge (now gone), contain three or four beds of gypsum in irregular lumpy

[1] Nadi = small stream, in size between a river and a mountain-torrent. In future "Nadi" will be written "N."

[2] Briefly mentioned in the Manual of the Geology of India, Part III, p. 454. See also a paper by myself (Records G. S. I, Vol. XXII, p. 137) in which I estimate the available amount at 37,400 tons.

masses. It is white, micro-crystalline, and very soft. It is forming at the present day in some places, and is evidently the joint product of the sulphur-springs and the massive limestone that are plentiful near Naini Tál. There is hardly a sufficient quantity to go far as an artificial fertilizer for the soil, for which purpose it is in some request; but for making selenitic mortar for building and canal-works (as strongly advocated by Colonel Thomason, R.E.) there is practically an unlimited supply for local uses, obtainable at little cost.

Wherever the Siwalik conglomerate flattens out into a gentle anticlinal or synclinal, the division between the Recent and Siwalik deposits cannot be made on petrological grounds, especially when the Recent gravels have been cemented and hardened by the deposition of lime. The gravels on the plainward edge of the hills forming the Bhábar, and the alluvium of the plains, also come under this heading; but they lie outside the pale of this memoir.

No glacial beds.

I have met with no deposits of material, angular, or otherwise suggestive of the agency of ice. It would indeed be strange if glacial conditions had prevailed during the Recent period in this part of India. Some angular conglomerates in the Nehál N. and in the Gola R. near Amratpúr, which cling to the hillsides, are no doubt scree-material. They resemble similar deposits in the Dehra Dún, near Rájpur, which present somewhat the appearance of a boulder bed, but are more probably an accumulation of scree-material: the ridge up to Masúri hill-station, which rises very steeply above these deposits, would constitute a *vera causa* for the accumulation of such angular débris in that locality.[1]

Siwalik conglomerate: U. Siwalik.

The Siwalik conglomerate, in the majority of cases, is found to be sharply marked off from the Recent deposits by a very distinct uncorformability, except in

[1] Connected with the glacial question, the presence of very distinct ancient moraines (two lateral and a terminal), a few miles south of the present Kedarnáth glacier, and some hundreds of feet below it, show very clearly the limits within which the glacier has contracted during the Recent period. Major-General McMahon (Rec. G. S. I., Vol. XII, p. 68) gives similar evidence from observations made by him during a tour through Hangrang and Spiti.

such cases as I have mentioned, in some of the dúns, and wherever the former are comparatively undisturbed. These exceptions, however, give a reasonable colour to the supposition that there was never a continuous unconformability between the Recent material, now in the process of forming, and that of the uppermost Siwaliks. Notably in the Pátli dún, and in the Kotah dún at its eastern end, is it impossible to separate the one from the other; and I am inclined to think that this is somewhat of, or very nearly, a real sequence, rather than a deceptive conformability.

The Siwalik conglomerate is composed of much the same material as forms the present stream-beds. Very seldom it is somewhat angular, but generally it is well rounded. The pebbles are of large size, chiefly of Himalayan rocks, and with a considerable admixture of earthy sand, of buff or dark yellow colour. Near Dhanaor Chaor on the Nandhaur R. there occur Siwalik conglomerates, often vertical and almost entirely composed of large blocks of Nahan sandstone. Many clay and loamy bands, of brown and yellow colours, are interbedded with the ordinary conglomerate. The latter increase in quantity low down in the formation, and are often studded here and there with pebbles. False bedding is very common; and the rock is hardened in places by a deposit of lime between the pebbles. Over the area in which I have worked, I have seen very little horizontal variation in the material forming the conglomerate. An attempt to establish a difference between the pebbles at the E. and W. extremities failed, with the exception that in E. Kumaun the presence of large numbers of well-preserved granite and trap pebbles is clearly due to the existence of the parent-rocks immediately north of the sub-Himalayan zone. Seeing that their general source must have been the higher Himalayan range, and that lateral uniformity is the chief thing noticeable in that range, so far as its composition goes, this is exactly what we should expect. The following is a list of the commoner pebbles, between many of which innumerable passage-forms exist:—

Himalayan rocks	Purple and white and grey quartzite	most common.
	Purple and grey slate	common.

Himalayan rocks	Purple and greenish gritty quartzites	common.
	Fine conglomerates	do.
	Lydian stone	rare.
	Decomposed greenstone	do.
	Vein quartz	common.
	Well-preserved trap	common locally.
	Ditto granite	do.
Older Tertiary	Soft, brown and pepper-and-salt sandstone (Nahan)	common locally.
	Greenish-grey shales	rather common.
	Ochre and dark brown shales	do.

The above gives a fairly accurate general idea of the composition of the pebbles. This is all that is necessary here; for to detail the composition of every pebble would be to describe prematurely the petrology of the whole of the higher Himalayan range.

A very constant character of the conglomerate is the alternations of coarse and fine bands, and of sandy, loamy and clay beds with it. Only in the Kotah dún, and at a few places near Dúrgapipal, where outliers on the Himalayan rocks occur, is there any rapid, radical change in the nature of the conglomerate. It is there seen to be very angular, and composed of the particular rocks immediately in the vicinity. There is some doubt, however, as to whether all these should be classed with the Siwaliks, or with the superficial Recent accumulations. More probably they represent those intermediate strata which, as already indicated, blend, though in an imperfect way, the Siwalik with the Recent period.

As a whole, the Siwalik conglomerate may be said to be more ferruginous, and to be composed of larger and coarser material in its upper part, than at lower horizons. In the lower beds, the sandy-clay partings become more frequent, and the material of the conglomerate finer, though different-sized pebble-beds alternate as before.

In numberless sections there is seen to be a petrological passage from the conglomerate down into the stage next to be described. I think this passage to be a real one, indicative of a gradual though decided change of conditions at the time of its deposition; but, as other observers in the country further north-west have found local unconformabilities in it, I shall have to refer to the subject again later

on. The Siwalik conglomerate usually interbeds itself rapidly, but still gradually, with the sand-rock below.

The thickness of the Siwalik conglomerate is very variable, according as the locality is near to or distant from a large river. A calculation across the ridge south of the Pátli dún, along the line of the Gaujpáni Rau, gives a thickness of 2,970 feet; or a little over half a mile. Mr. Medlicott mentions[1] that in some localities, in the country further north-west, the conglomerates are at least 5,000 feet thick.

Sand-rock stage.

Although the previous formation passes down into the M. Siwalik, or sand-rock stage, the latter is sufficiently well-marked off from the former, through its main thickness, to warrant a separate description. Previous writers on the Sub-Himalayan zone have been unanimous in naming its representative elsewhere a soft sandstone. That it passes down into soft sandstone and shales, undistinguishable from the Nahans, I shall show later on; but, seeing that there is a large thickness having the characteristics of a sand-rock, rather than a sandstone, besides possessing other peculiarities, I think it not unnecessary to give this division of the Siwaliks the above name of the sand-rock stage. The passage of it down into the Nahans was a moot question when Mr. Medlicott wrote his book. It is entirely owing to the clearer nature of the sections, which are easy to read in the districts covered by this memoir, that I can make this statement so confidently and without reserve. But, although the passage is undoubted, the gradations are rapid; so that there can only be a very small zone which is doubtfully the one or the other. Hence the mapping of the boundary, though in a sense arbitrary, is not so to any great extent. A very little way on each side of the boundary, the material is distinctly sand-rock on one side, and sandstone on the other. A simple and practical distinction between the two is, that while the sand-rock crumbles under the hammer and refuses to make a coherent rock speci-

[1] Manual of the Geology of India, Pt. I, p. 536.

men, the sandstone, however soft, can always be trimmed into a solid block. For this reason the one is useless, and the other useful, for building purposes.

In the main, the sand-rock is a pure, micaceous, slightly ferruginous, and sometimes felspathic, sand as to its basis. It is of sugary texture, and without jointing or other divisional planes. Pale ochre colours generally prevail ; but a banded coloration is more common, in which the former are associated with pale blue greys, chocolate browns and pale purplish tints. Sometimes the rock weathers white and sometimes pepper-and-salt colour. Reddish brown clays are freely interstratified, and grey clays and loams are very prevalent in its uppermost layers. It is said by Mr. Medlicott to resemble the Swiss molasse in texture and composition. A characteristic feature of the sand-rock is the presence of numerous nodular layers, apparently of the nature of concretions. They are sometimes massed into a thin tabular layer, and they vary in thickness from a few inches up to two feet. Their surfaces are wavy and mammillated, owing to the concretionary action round different centres interfering and mingling the one with another. These layers become so hard as to ring unmistakeably under the hammer, and to stand out in relief in the river-bed and scarp. They are sometimes broken up into distinct masses of remarkably spherical shapes, like the concretions in the lower Kelloway rock of the north of England. Not unfrequently they appear in grotesque forms like flints. Occasionally, as in the Peláni R., they become so like flattened pebbles, in their distinctness from the rock matrix, that one may be easily deceived by them. In the Rámganga R., among Nahan sandstones, some two or three miles from Kálagarh, there are similar concretions which I may notice here. They are a foot or more in diameter, and of a different colour to the rest of the rock. Their appearance is, in fact, that of stray boulders scattered in a finer matrix. I was fairly misled by them at first; but a search for scratchings and groovings proved that the bedding of the supposed boulders always coincided with the bedding of the sandstone in which they lay. In every one of thirty or forty cases

that I examined, this held good, and was a satisfactory proof that they were merely concretions, and not transported blocks.

There are two sorts of pebble-beds, or fine conglomerates, occurring in the sand-rock formation. None, except in the upper parts where it is passing into the Siwalik conglomerate, have any predominating effect over much of the area covered by this memoir, though an exception will be noted hereafter. Their pebbles are always small and insignificant, and of a different composition to those of the U. Siwalik stage. One kind consists of thin strings of white quartz pebbles three-fourths of an inch long. Thin layers of irony concretions sometimes accompany these pebbles, and give a dark-brownish appearance to the rock. The other kind of conglomerate is made up of rolled clay balls. They are often scattered sparsely through a sandy matrix; but in other places they become more crowded, and make up the so-called clay-conglomerates, similar to those described by Cautley in the Kálawala Rau. These beds may easily be confounded with the nodular clays which are frequently interstratified with the ordinary sand-rock. The latter, however, are quite distinct. The clay pebbles are brownish ochre, and sometimes Indian yellow coloured, and so soft as to be scratched by the finger nail. Sometimes a few brown sandstone pebbles are mixed with them.

Nests and strings of lignite and coaly material, bright, shining, and breaking cuboidally, are very common. They are very small, though occasionally a somewhat larger tree trunk has been fossilized, and given rise to unreasonable expectations of coal. Nothing resembling a seam is known. It may be as well to state therefore, at once, that there is not the slightest chance of finding workable coal in these hills.

The sand-rock formation, as a whole, is so soft that the country, wherever it crops out, is in a state of rapid disintegration. The southern portion of the Chándi hills is a good example of this decay of the hillsides, which there goes on at such a rate that the forests are unable to keep sufficient hold to thrive.

A good deal of the material of the sand-rock was examined by me, by means of washings and the microscope, in order to trace the origin of the gold which is obtained in many of the rivers. The pure kind was shown to be a fine-grained, pure sand, with a small amount of argillaceous material. Clear quartzes, in slightly-rounded grains, formed the bulk of the rock; white mica, in flakes, was very common; amethystine quartz was also numerous, together with some deeper red coloured fragments of cornelian and jasper; and a fair percentage of iron oxide (magnetite), in fine rounded grains, was always discernible.

In washing the material by hand, the mud and the mica flakes are the first to run away; the quartz forms up next on the edge of the plate; and last of all there is left a black border of magnetite. If gold had appeared in the washing, it would have been found next to the border of magnetite; for it is a similar black magnetite residue, among which the precious metal is found by the washers of the Sona N. Certain portions of the sand-rock are, in addition, rich in felspar in irregular grains, and black mica. The whole of the material of the rock is then much less rounded by water action. It is the magnetite and black mica which, mingling with the other constituents, give the rock in some places the speckled, or pepper-and-salt, appearance.

Taking the sand-rock stage altogether, we may say that the upper portion of it is largely composed of the sandy and loamy beds. The concretionary layers set in lower down; and lower still the fine quartzose conglomerates, and the clay conglomerates. The concretionary sandy layers, and the conglomerates, continue down to the base of the stage, and even pass into the upper beds of the Nahan sandstone.

The thickness of the sand-rock stage is very great; and appears sometimes to vary inversely as the thickness of the Siwalik conglomerate. For instance, there are 7,260 feet of the former, calculated along the Rámganga, from the Nahan boundary up to the Siwalik conglomerate; whilst in the Kotri N. the thickness of the corresponding band is 8,910 feet. It is true the northern boundary of the former

band is not quite a natural one, so that the thickness there should probably be a little more. On the other hand, the conglomerate, which begins to thin at the Rámganga, dwindles down to a scarcely recognisable bed in the Kotri N. Its northern edge is, however, a fault, though, as will be shown later on, it is improbable the conglomerate here was ever very thick. Should it be found true that the thickness of the sand-rock varies inversely as that of the conglomerate, we should probably have to regard the upper part of the former, in one locality, as contemporaneous with the lower part of the latter elsewhere.

Nahan sandstone.

The Lower Siwalik, or Nahan beds, as already mentioned, may be called sandstones; for they are, as a whole, much more indurated than the rocks of the sand-rock stage, although the two merge into one another conformably. The Nahan sandstone is generally of darker colour than the sand-rock, brownish and greenish-brown tints prevailing, with sometimes a bluish-grey. It is very micaceous, and occasionally felspathic. It is never so purely silicious as the sand-rock, but contains more earthy and secondary ferruginous products. Purple, dark reddish brown and greenish shales, finely laminated, are interbedded with it, especially at the lower horizons. It is possible that this preponderance of red shales in the lower parts indicates an incomplete passage into the uppermost Sirmúrs; but such a passage has never been actually proved in this region: that is to say, the lowermost Nahans never show the nummulitics underlying them in a normal section. There are some conglomerates similar to the clay conglomerates of the sand-rock, but they are generally more compact and more firmly aggregated. In the upper horizons there are also some concretionary layers of the same nature as, but less distinct than, those in the stage above. There are irony bands in some of the lower purple shales, which near Dechauri swell out into considerable beds of brown hematite. This was once worked, and smelted along with the Rámgarh iron ore brought down from the higher hills for the purpose. The absence of coal in the neighbourhood has rendered this unprofit-

able, notwithstanding the large supply of charcoal always available from the surrounding forests.

A very conspicuous difference between the sand-rock and the Nahan sandstone is that the latter is traversed by numerous joints, parallel and at right angles to the bedding planes. Thus, the rock splits with readiness into blocks and slabs. The jointing is more marked in the lowermost Nahans, and less in the uppermost.

The thickness of the Nahan sandstone canno be definitely estimated; because, in the first place, the base is nowhere seen, and, in the second place, the strata are folded in the typical zones with an unknown amount of fold-faulting. In the Peláni N. the middle Nahan sandstone zone is 4,950 feet thick, from the base of the sand-rock down to the anticlinal north of the Nahan-Siwalik boundary. The middle band in the Kotri river gives a visible thickness of 6,270 feet. Thus, we can only say that at least it is as thick as the latter value.

Whole of Siwalik series.

Regarding the whole of the Siwalik series, from the visible base of the Nahans up to the top of the Siwalik conglomerate, one is impressed by the aspect of a great conformable and connected formation, but one which must have taken a long epoch of time for its deposition. There are three standards by which one is able to infer that that epoch was of great duration. In the first place, the immense thickness of the deposits (which average at least 16,500 feet, or over three miles) render it impossible, except on some cataclysmic theory, that they could have been accumulated in a brief interval. Secondly, the difference in the consolidation of the rocks forming the lowest and highest beds in question (which difference is well seen in the Nahan and middle Siwalik stages), shows a great aging of the lowest members. Thirdly, the relative differences in the disturbance which has affected the lower and higher parts of the series, and which we shall see later on resulting in the apparent anomaly of marked unconformability between the uppermost and the lowermost beds with continuous conformability between consecutive stages, point in the same direction and argue a long epoch of time.

Sirmúr series, nummulitic stage.

Although, for reasons given above, the detailed description of the nummulitics will be left until the Himalayan group of formations can be taken in hand, I may make a few remarks about their petrology here for the sake of uniformity. They are characterised by being thinner bedded and less massive than any of the previously described formations. A pisolitic iron ore bed is found at the bottom of the series in some places, just as in the area examined by Mr. Medlicott. This passes upwards into grey, and sometimes slightly purple, shales and sandy beds; with earthy calcareous nodular beds, and other thin strings of purer dark blue-grey limestone, containing nummulites and other foraminifera, besides mollusca and fragmental vertebrate remains. Still higher in the stage, the rock becomes marked by more shales, the limestone dies out, and sombre purple, grey, and greenish-grey coloured shales take their place. Some few purple, gritty bands next come in, and suggest a beginning of the Dagshai stage in this locality. The whole of the Sirmúr series here exposed is very thin, becoming thinner as we travel east of the Ganges. A few hundred feet is the maximum attained.

CHAPTER IV.

DISTRIBUTION AND STRATIGRAPHY.

In describing the distribution of the different rock stages, it will be well to take separate portions of the Sub-Himalayan zone, bounded in a more or less natural way, and detail the geology of each. Certain considerations also make it advisable to begin in the middle of the region where the stratigraphical relations are the simplest, namely, the Kotah dún, and to travel in imagination west-northwest; taking up one after the other of the minor dúns and the intervening country until Hardwár is reached. After this the rest of the Sub-Himalayan country of East Kumaun will be gone over in the opposite direction as far as the Sárda R.

THE KOTAH DÚN.

The Kotah dún is about fourteen miles long, stretching in a direction N. W. and S. E., and lying to the east of Rámnagar. The plains at the foot of the dún are about 1,250 ft. above the level of the sea; whilst the dún as a whole may be regarded as a plateau, which has been elevated 750 ft. above the plains, and become crumpled as to its strata along its south-west border. The south-east portion of that border is merely an escarpment lower than the dún itself, whilst towards the N. W. it rises to the insignificant height of 300 ft. above the dún, forming a low range of hills separating the latter from the plains (see sections I, II, and III). On the north-east and east the dún is bounded by a series of spurs, running out from the main range of the Lower Himalaya. Towards the north-west, near the Kosi R., the dún comes to an end by the fusion of these spurs with the low bordering hills. The eastern portion of the dún is more or less cultivated, bright patches of green fields and small villages being scattered for some distance round about the deserted buildings of the Dechauri Iron Works. On the other side of the Dabka R., villages cease in the dún proper, and reserved forest takes their place. The Sub-Himalayan zone, however, is continued some way north of the dún, and is bounded by the usual reversed fault between the Nahan sandstone and the Himalayan slates. This divisional line will, in future, be called the main boundary fault, as named by Mr. Medlicott. It is remarkable for its constancy over the whole area treated of in this memoir, in which area it is always the northern limit of the Sub-Himalayan rocks, and the southern limit of the Himalayan slates, &c. The portion coloured on the map as Nahan sandstone, between the north edge of the dún and this main boundary, presents the ordinary characteristics of the Nahan rocks elsewhere, so far as its petrology goes, save that there is a strong band of brown earthy hematite 1¼ miles east of Dechauri, as already mentioned. These Nahan beds all dip N. E. or N. N. E., with a few ocal exceptions, at pretty uniform angles of between 40° and 60°. This position of dipping

towards older rocks is a normal one in the Sub-Himalayan zone, as all students of Himalayan geology will be aware. Its production has been accounted for in a variety of ways. Some observers see in it an entirely inverted state of the rocks; others would represent it as the effect of a gigantic fault; whilst others again throw doubt on the fault theory, and regard the main boundary as an original limit of deposition, complicated by crushing. It would be premature to discuss the subject here, more especially as, in the process of describing the country bit by bit, its full meaning will more clearly unfold itself. Whatever be the nature of this boundary, it has always claimed an important share of attention, as being the greatest master-feature of the south face of the Himalaya; inasmuch as it relentlessly divides in a natural way the Sub-Himalayan from the Himalayan region.

At the foot of the Nahan sandstone spurs the winding edge of the dún marks the in-coming of the great chaors, or plateaux, forming the Kotah dún. They are uniformly composed of slightly coherent coarse gravel, or torrent-boulder beds, and sandy clays, which lap round the eroded edges of the Nahan sandstone, just as the deposits of the plains lap round the edges of the still younger rocks. There is every reason for supposing the greater part of these beds to be uppermost Siwalik in age, the section being a parallel one to that at Simbuwala described in Mr. Medlicott's memoir (p. 111). At first sight, their level arrangement, as exhibited in some parts of the Dabka and the Baur (Bhaol)[1] rivers, inclines one to the only other belief tenable, namely, that they are still more recent gravels than the Siwalik, which might be expected to be found overlying unconformably the real Siwalik conglomerates. This idea was the first to obtrude itself on my mind. Detailed work, however, showed me the following excellent reasons for discarding it, and assimilating them with the Siwaliks, even though that assimilation should bring the top of the Upper Siwalik stage much higher in the scale than is commonly supposed, and within measurable distance of the Recent river

[1] Wherever names of villages and rivers differ, the first written in the text is the more correct or more modern one, and is so marked on the 4-inch Forest Survey maps; the name in brackets is that marked on the older 1-inch Trigonometrical Survey maps.

deposits :—(1) There is no unconformability visible between them and the undoubted Siwalik conglomerate forming the low range between the dún and the plains. (2) Slight sharp local flexures can be seen in them here and there. (3) Every gradation of dip, from the horizontal beds of the dún to the distinctly inclined strata of the range south-west of the dún, can be made out. (4) They cannot manifestly be imputed to any Recent river-bed. (5) Even where horizontal, they are of great thickness. (6) Wherever undoubted modern gravels can be seen covering certain portions of the dún their thickness is trivial, and the bed-rock can be nearly always made out underneath.

The detailed sections which follow will illustrate the stratigraphy of the Kotah dún, and establish the six propositions just enumerated.

Baur N. (Bhaol N). (1)

This river presents many shingly terraces, some overgrown with vegetation, which are manifestly of recent origin; whilst, on the other hand, still higher banks, sometimes in two or more steps, and rising 200 ft. above the present river-bed, mark the ancient levels of the river as it cut its way through the horizontal Upper Siwalik beds. From one end of the river to the other the Siwaliks are horizontal, save for a dip of not more than 3° S.W. near the ironworks. The river runs very nearly along the boundary between the dún and the higher Nahan hills. Sometimes it actually follows the boundary, and shows sections of the Nahan sandstone and purple shales with the conglomerate horizontally disposed against them, as against a cliff. In other parts, especially towards the south, the boundary is a little on the eastern side of the river. The conglomerate is generally, throughout this river section, hardened by calcareous infiltrations.

Dhúni gádh (Dhooni gádh, a few miles W. of Bhaol N.).

From a point near 1,510 ft. *bar.*[1] there are exposures of horizontal beds of the Siwalik conglomerate with the sandy clay basis, sometimes hardened. They continue horizontal down to a point due west of 1,556

[1] *Bar.*—Point on the Forest Maps fixed barometrically.

ft. *trig.*[1] Here there is a steep scarp on the left bank of the river showing a gradual inclination of the beds S.S.W. The increase of dip can be watched, step by step, as it gradually achieves the angle of 40°, which sinks again to 30° near where the stream issues into the plains. At several points along the river-bed Recent deposits of calcareous tufa are seen in small quantities, formed by a constant dripping of the water from the banks above.

Karar gádh (Ghoráni gádh, 1½ miles further W.).

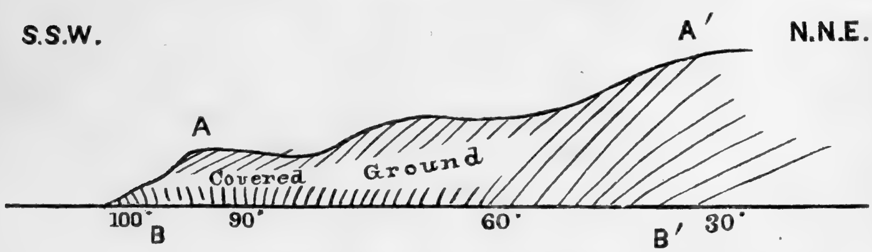
The upper reaches of this stream show horizontal conglomerates similar to those just mentioned. No deflexion from the horizontal can be detected with a level in the steep scarp near Okjálu páni, nor under Mania tila. This horizontality continues down stream until about ¾ mile of the outlet. Numerous good exposures then show a gradual bending over towards the S.S.W. and S. There is nothing that can be construed as an unconformability between the horizontal beds and the inclined ones; nor is there any distinction between the material forming either set of beds. The dip increases gradually, the increase being measurable degree by degree, until at the outlet by Komola the beds are vertical, striking E.—W. very nearly. For about two miles up this stream the left bank is flat and low, being covered with recent alluvium composed of fine clay, and with very numerous deposits of calcareous tufa.

Ladwa gádh (Larwa gádh, one mile further W.). (2)

Except for the last mile or so down stream, the conglomerates here are perfectly horizontal. A gradual dip S.S.W. then sets in until the vertical is reached and passed, and the dip is 100° S. S. W. (or 80° N.N.E. inverted). At the south entrance to this stream I very nearly made a mistake of interpretation, which is sufficiently instructive in itself to be mentioned. Just at the point where both sides of the stream rise into steep banks, the right bank for some distance shows inversion to the north, which gradually becomes vertical in 20 or 30 yards of exposure up stream. The cliff showing this is about 20 feet high, but the upper 15 feet are

[1] *Trig.*—Point on the Forest Maps fixed trigonometrically.

composed of horizontal Recent beds of gravel and clay, which seem to be sticking to the sides of the bank. A little south from this point I was astonished to see what appeared to be those upper gravels and clays dipping S.S.W. at an angle of 30°. The lower portion of the bank was here much obscured by talus, but at intervals I could still make out nearly vertical conglomerates just visible above the river-bed. I was immediately impressed by the belief that there must be here a set of inclined gravels and clays, of younger age than the Siwaliks, and superposed uncomformably upon them. I could see no way out of this interpretation for some time, until I worked up stream, when I made out the points illustrated below—



At A and B was the supposed unconformability between the inclined gravels A and nearly vertical Siwalik conglomerate B. But since A and A′ were continuous, B and B′ also continuous, and so also A′ and B′; we have (using = in the sense of conformable or of the same age)—

$$A = A'$$
$$B = B' = A'$$
$$\text{Therefore } A = B$$

I came to the conclusion, therefore, that the beds at A and B were of the same age. I then set to work with coolies to pick away the section. I was rewarded by finding the loosely aggregated gravels becoming firmer as the material was cut into, and by also finding the upper beds at A bend round rapidly to the vertical, and so become actually continuous with those at B. I have taken the pains to describe this carefully because it is an example in miniature of what

is so frequently seen in the higher Himalaya. I refer to the apparent flattening out of the dips on the hillsides, as contrasted with their steeper dips in the river beds. One more remark may be made with regard to the section. A and B contrast very much in hardness or degree of consolidation, B being much more solid than A; but the same was observed between A′ and B′ where the section was seen to be absolutely continuous. Probably much of this contrast may be imputed to the loosening of the material on the hillsides, due to percolation of rain-water, and a little to the hardening effect of the stream water carying lime in solution.

Horizontal accumulations of gravels, calcareous tufa, and alluvial clays cover the top of the cliffs on the east bank near the south end of the gádh. Still higher up the stream they form a barrier over which the water pours in a cascade. A confused mass of the tufa in large mis-shapen blocks fills in the stream-bed beneath the barrier. It is of pale grey or dirty white colour, much honeycombed and in appearance twisted like ropy lava.

Gothna gádh and Bhira páni (1¼ miles further W.) (3)

These streams show some few deposits of calcareous tufa with the Siwalik conglomerate beneath dipping at various angles S. W.

Sanáni gádh.

In the higher parts of this stream the conglomerates are horizontal, with a wide alluvial flat on the left bank, and some deposits of tufa. The latter increase in size and thickness towards the mouth of the stream, making many very picturesque cascades as the water descends from one level to another. About ¼ mile from the mouth there is a great fall into a widened basin with clean cut sides, which reveal the Siwalik conglomerate dipping at 70° and 80° S.S.W., and the Recent gravel and alluvium, with thick tufa beds, disposed horizontally upon them.

Chúna Khán. (4)

This is a steep cliff, or escarpment, fronting the plains, about 50 ft. in height, and having a mass of calcareous tufa deposited in shelves on the edges of the Siwalik conglomerate. The latter is inclined at 40° and 70° S.S.W. The tufa is largely quarried here for lime.

These form a wide river-bed and show to the south dips of 5° S. S. W. and dips of 5° and 8° N. N. E. further north, that is to say, a flat anticlinal is cut through. The northerly dip is coincident with the in-baying of the alluvium of the plains along the bed of the Dabka, which takes a wide turn to the west in this place. To the west of the Karkát N. there are left two islands of the Siwalik conglomerate; the near one of which is a flat anticlinal, with axis W.N.W. to E.S.E., and with steep dips on the south side close to the plains, and low dips on the north insensibly taking the conglomerate underneath the E.-W. reach of the Dabka N.

Dhauntia sót, Karkát N. and Káli gádh (stream between Pawalgarh and Belparao). (5)

From Pawalgarh (6) in a northerly direction, a continuous set of cliffs is exposed, showing the conglomerate scarcely consolidated, first with a slight dip towards the south as it recovers from the similarly slight dip to the north in the Karkát N. This quickly changes to horizontality, which is retained for about a mile, when another steady N.N.E. dip of 3° gradually begins and accumulates to as much as 7° at the point where the real dún is reached, north-east of the Kailkhúr (Kailakhoor) (7) hilly mass. The river-bed suddenly widens out here, and horizontal beds of conglomerate and more or less coherent gravels continue across the level expanse of the dún. It is therefore evident that the dún strata are but a portion of a wide, flat synclinal; whilst those exposed in the lower portion of the Dabka, where the low range of hills is cut through, are a portion of a wide, flat anticlinal. As the latter is traced further north-west to the Khichri N. (Kichulee N.) we shall see it increasing in steepness as the hills increase in size. At the same time more strata are brought into view, and we have an accumulated thickness of conglomerates and clays of sufficient magnitude and disturbance to completely negative the idea that they can belong to anything but the normal Upper Siwalik stage.

Dabka N.

On the north side of the Kotah dún, just where the Dabka N. emerges from the higher Nahan sandstone hills, there is a curious sharp monoclinal flexure in the conglomerate beds which takes them

up to an unconformable position on the top of typical Nahan shales and sandstone. The long stretch of perfectly horizontal beds exposed across the dún is rudely broken by this sharp bend; and if there were still any doubt as to whether the latter were Recent or Siwalik in age, I think the occurrence of this flexure would dispel it. (See section II.)

Still higher up the Dabka there are a few small outliers of the conglomerate, the northernmost of which is resting on Himalayan rocks. They are probably of younger age than the dún conglomerates; and, though I class them with the Siwaliks, they must be the uppermost of those beds, which probably link or merge them with the Recent deposits of the present rivers.

Khichri N. (Kichulee N.).

During the course of this river through the dún, the beds are horizontal just as in the Dabka; but, when the dún is ended, its passage through the low hills to the south is a deep-cut gorge among more disturbed strata than we have yet seen. (See section III.) It begins abruptly near Sitabani temple (8), the level of the dún giving way to a line of steep scarps and bare cliffs, into which the river dashes. The country here is very wild and luxuriant, and full of large game. Standing on the top of one bare cliff, with spear grass, creepers, and sál forest all round one, we may look across the Khichri gorge and with a field-glass make out on the opposite cliff bed after bed of warm brick, or ochre coloured conglomerate and clay. There are hundreds of feet of it, and among its ledges we may see a solitary sámbar, or numbers of actively climbing serow. The skeleton of the hillside thus laid bare is a silent and grand witness to the slow but irresistible action of running water, combined with earth movements, in cutting out that knife-like gorge. The sight is the more impressive, I think, from its being brought to one's notice among these flat plateaux and low hills, which in many of their larger features retain almost unmodified their shapes as impressed on them by the forces of upheaval. It is to one of these forces that the abrupt termination of the dún at Sitabani, and the sudden line of cliffs to the south, is

due; for a fault runs E.S.E. and W.N.W. at that point, with upheaval to the south; an earth-movement which has hoisted up these conglomerate masses to their present position, and which has not yet been masked by the levelling of denudatory activity. Only the solitary thread of the waters of the Khichri has gone on for ages eating through the rocky gorge as the hilly mass rose; its cutting power thereby quickened and strengthened, just as the cutting power of a circular saw is proportional to the pressure of the wood or metal against it.

The fault appears to die out in the direction of the Dabka, being represented in the latter river by a sharp bend only (see section II). It also dies out in the opposite direction. About ¾ mile up the Jáman Páni sót (9), north-west of Sitabani, a good illustration of the fault can be seen. The beds to the north are horizontal, those to the south being at first vertical, and then decreasing gradually in their angle of dip up to the top of the ridge, where they are about 30° S. W. Beyond this in a W. N. W. direction the fault gradually comes to an end; for in the Tehra (Taila) sót, and along the road from there to Bhalaon (Baloon) forest bungalow (10), the dip is conscientiously towards the north-east, at very low angles of about 5°. Thus the structure seen in the Dabka N. is returned to very nearly in that direction owing to the extinction of the fault.

Down the Khichri N. from Sitabani the dips are also to the south, but rather to the east of south than to the west. The first visible dip is 60°, which lowers to 15°, and then to 10° near Sál Khét chaor, about a mile from Sitabani. The beds then flatten out into a synclinal, on the south side of which the dip is N.N.E. at 10° for another mile or so, where a flat anticlinal runs along the Jirar sót (11). South of this the dips continue S.S.W. as far as the outlet from the hills, where the culminating amount is 27°. The lowest beds seen in the Jirar anticlinal are rather more sandy and clayey than any of the other conglomerates.

Here there are seen dips of between 30° and 20° S.S.W. from the south edge of the hills up to 1,432 feet, *bar.*

Bahárdagarhi sót. (12)

Tehra sót (Taila sót) (13).

In this stream, on the contrary, the dips are on the other side of the anticlinal, namely, in a direction E.N.E., and this direction continues completely across the north-west end of the Kotah dún. At the point where the Garja-ka-sót (14) is crossed the conglomerates dip at 30° N. E., and they keep this dip up to the 1,893 feet hill to the north. Their junction with the Nahan sandstones is not seen in a definite exposure; but there seems no doubt that it is a reversed fault. The material of the conglomerate here is somewhat more angular as the higher hills are approached, a fact indicating the limit of deposition of the Upper Siwalik stage in this locality.

Kotah dún as a whole.

The structure of the Kotah dún and the fringing hills, therefore, is remarkable for the very perfect way in which the features of positive and negative contortion impressed on the Siwalik strata have been directly influential in determining their present surface features. The flat dún is composed of level conglomerates and clays, whilst the low hills to the south, in height and importance, are determined by anticlinals the steepness of which corresponds to the steepness of the hills. Wherever these low hills slope gradually down to the flat country, the dip of their strata falls gradually in unison with it. On the other hand, at Sitabani this is not the case, the strata do not dip gradually under the dún, but are turned up sharply in the opposite direction, owing to elevation along the south side of the fault. That is to say, the sudden way in which the hills rise to the south is nothing more than the obvious result of upheaval in that direction with production of a fault-scarp. Again, at Chúna Khán and Madan Bhél, the southerly dip of the strata has increased rapidly to the vertical at the edge of the plains; and this corresponds to the very prominent steep low scarp, which one cannot fail to notice as we travel along the sub-montane road from Káladhúngi to Bael parao. The extinction of the Kotah dún to the north-west is a signal that the gentle undulations of the Upper Siwalik strata are giving way to the more compressed state of things which we shall find obtains in the country now to be described between the Kotah and Pátli dúns.

A word or two may be said here about the horizontal sections which accompany this work. They are drawn with the horizontal and vertical scales equal, from the heights and distances given on the 4-inch maps reduced one-half. Taking the datum line at the level of the sea, this gives sufficient room in the section to represent the folds of the strata without the exaggeration which follows on an increase of the vertical scale. By looking at the sections fore-shortened lengthwise, any desired exaggeration for the sake of distinctness can be obtained. The three sections across the Kotah dún show the several steps by which an almost completely horizontal disposition of the Siwalik conglomerate becomes raised into folds and faulted.

COUNTRY BETWEEN THE KOTAH AND PÁTLI DÚNS.

The Sub-Himalayan zone here, also, is divided from the older rocks by a reversed fault, presenting no peculiarities that need be noted in this place. Its position can be seen on the map. The lowest member of the Siwalik series, namely, the Nahan sandstones and shales, though keeping generally to a position next this boundary and north of the Upper and Middle Siwalik stages, has become somewhat more entangled with the latter. This is owing to the greater lateral compression of the area, and the appearance of fresh outliers of the conglomerates north of their proper zone. The scale of formations is supplemented here by the in-coming of the Middle Siwalik sand-rock beneath the Upper Siwalik conglomerates, and next to the plains. The map, therefore, shows three bands of Sub-Himalayan rocks, which are respectively, beginning from the south, the Middle Siwalik sand-rock, the Upper Siwalik conglomerate and the Lower Siwalik or Nahan sandstone. In addition, there is another broken line of outliers of the conglomerate to the north of the main mass.

I will now detail a series of individual sections.

Kosi R.

This river is larger and more important than any of the smaller streams we have yet met with west of Káladhúngi. Its channel lies along a wide, open

picturesque valley through much of its course, and especially in the Upper Siwalik tract. This valley forms a natural highway for Bhootias and other hill-men from the higher parts of the Himalaya, a race of thick-set, swarthy men, with long locks of black hair and Mongolian features; who, accompanied by their flocks of sheep and goats laden with little bags of borax, red pepper and other products of their simple trade, form a characteristic element in the landscape as they slowly make their way down to the plains. It was also until recently a highway for the troops marching to the military stations of Ránikhet and Chaubattia: and in addition much of the timber wealth from the surrounding forests is discharged through it down to Rámnagar. These facts help out the idea which struck me forcibly, *viz.*, that the valley was once filled by a mightier river than now occupies it; whilst the connecting Upper Siwalik beds between it and the Rámganga R. seem to point to the hypothesis that a connection between the two rivers once obtained in Upper Siwalik times; that in fact the Rámganga was once a tributary of the Kosi, and that it has since been gradually diverted from it by earth movements.

The lower north and south reach of the river, between Rámnagar and Dikoli, is characterised by broad terraces of Recent gravels rising about 200 feet above the level of the river. They form chaors a mile wide on each bank, with only a low cliff at their base, where the underlying Siwalik conglomerates are displayed. At Rámnagar the dip in the Siwalik conglomerate is 20° N. W. It trends more west on the opposite side of the Kosi, and gradually merges into the S.S.W. dip prevailing still further east along the foot of the hills. A mile west of Rámnagar, in the Chorpáni sót (15) the dip in the conglomerate is E. and E.S.E. at high angles of 60° and 40°; so that between Rámnagar and this sót there must be a synclinal, with axis running about N.N.E. At Ringora parao (16) a continuation of this synclinal is again seen in the low cliffs by the river side. It is very sharp, and is doubtless accompanied by some slight faulting along the axis. To the east of the Kosi in the Súk sót (17) (joining the Kosi near

Lakwa) the dips are 15° and 10° N.E., that is to say, conforming to the dips in the Tehra (Taila) sót. How the dip in these sóts merges into the N.W. dip in the Kosi along this reach cannot be seen, on account of the Recent gravels and the absence of cliff exposures; but it seems probable that there is first a flattening out towards the river, and then a new inclination N.W. consequent on a crushing at right angles to the axis of the sharp synclinal already mentioned.

The Kosi river, therefore, in this place is not so much a gorge cut out among the strata as a flat valley, depending for its main aspect upon the features originally impressed on it when the Siwaliks were disturbed. Higher up stream we shall find it becoming a gorge, and displaying great walls and slopes of rock through which it has eaten its course; but just here its task has been the simple one of finding a meandering basin among transverse gentle folds. The material forming the Siwalik conglomerate resembles that in the Kotah dún, with perhaps a slightly more marked quantity of the sandy and loamy matrix. Sandy clays are especially abundant near Ringora parao.

North of Ringora parao the south-easterly dip prevails for some way, and then veers towards the east, and then to N.E. and N.N.E. near Dikoli. The strata have, therefore, finally resumed their normal N.W. or W.N.W. strike, which is also approximately the normal strike of most Himalayan and Sub-Himalayan formations.

West of the Kosi gravel plateaux, on the right bank of the river, from a point half a mile south of Dikoli down to the latitude of Rámnagar, the country is low and undulating and much cut up into irregular small hills and water-courses. It is a labyrinth of hillocks, which very much resemble sand-dunes. They are deeply covered with jungle of a miscellaneous kind, and have much marshy ground and small lakelets between them. Exposures are rare, but the nature of the soil shows that the Middle Siwalik sand-rock has now come to the surface. A couple of miles west of the Kosi the dips in this set of rocks are, generally speaking, N.N.E., the regular normal Himalayan dip. It is, therefore, very probable that near

Dikoli, the division between it and the conglomerates which stretch away to Rámnagar is a fault, running nearly parallel to the Kosi, and also to the sharp synclinal flexure which we have already noticed.

The nature of the fault is not very well indicated; but it seems to be rather more of a horizontal displacement, or lateral shift (*décrochement horizontal*) than of a vertical fault. It may be that both movements are combined. In the Chorpáni sót the fault appears to have died out, and given place to a sharp bending of the strata instead; for there is a regular conformable junction of the Siwalik conglomerate and the sand-rock, both of which are dipping E.S.E. at high angles. The conglomerate is there seen, along a very good exposure, to establish itself by degrees, the pebbles gradually increasing in number and size, whilst the interbedded sandy clay material becomes less prominent. As a fault of the above kind is merely the ultimate result of a sharp bending of the strata, whereby a tearing along the line of bending is produced, it is necessary to be somewhat arbitrary in assigning exact limits to it. The general meaning and result of the fault is clear however: whereas the conglomerate is next the plains at Rámnagar, beds of the same horizon west of the fault (or horizontal displacement) have been carried forward in the crushing of the mountain mass to a great distance further north, where they are now found forming the Gauriagani and Karaungia ridge (S.E. of Chinal trig. station). Thus the beds west of the fault are in a more inclined condition, constituting but one-half of a great anticlinal, and having a uniform dip in one direction (see section IV); whilst those to the east of the fault are thrown into one or two undulations transverse to the great normal undulation of the former. Elevation on the west side of the fault, and depression on the east, would also help to bring about the same result; materially assisting the horizontal displacement, which I suppose to have been the more prominent factor of the earth movement.

North of Dikoli the valley of the Kosi closes in to a certain extent, and its waters pour through steep high cliffs of warm

tinted conglomerate. A little north of the suspension-bridge at Garjia (two miles N. of Dikoli) a solitary pillar of the conglomerate stands up in the middle of the river-bed, and is crowned by a small native temple. That rock marks the northern boundary of the Siwalik conglomerate, which is there dipping at 20° N. by E. The narrowing of the valley in this direction coincides with the assumption of the normal northerly dip. A greater vertical thickness of rock has been cut through, and the gorge is, therefore, narrow and shut in as at Sitabani. This northerly dip conspires with the similar dip in the Gauriagani and Karaungia ridge to the west, whilst to the east it is only retained as far as the commencement of the Kotah dún, when it gradually slackens off to the horizontal.

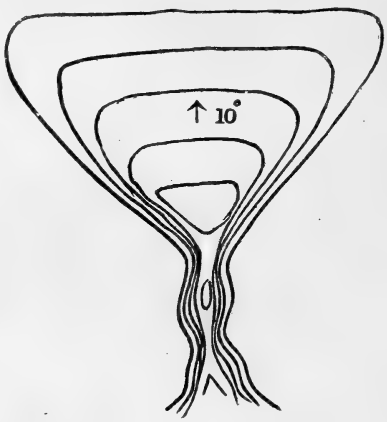
North of the temple rock the first exposure is seen in the Súki Rau (18); and here we have the Nahan sandstone dipping N.N.E. It is, therefore, clear, from the steady dip of these two formations in one direction (approximately), that the relation between them is of the same nature as between the Nahans and the still older Himalayan rocks (see sections I and IV); in other words, it is a case of younger rocks dipping towards older, with a reversed fault as the present result.

The next reach of the Kosi flows south-east along the boundary between the Upper Siwaliks and the Nahans. On the right bank broad gently sloping chaors of the conglomerate rise from the river-bed and contract upwards into the advanced northerly spurs of the Gauriagani ridge. Their slopes follow the dip of the conglomerate, just as the line of the ridge follows the strike of the same. This reach is broad and open, the visible expression of the folded flexure (now become a fault) along which the river ran readily, as compared with the difficulty it experienced in cutting through the ridge to the south. Near where the Dhangari (Thunghully) sót (19) joins the Kosi, the boundary leaves the river bed and turns away west. It will be well, therefore, just here to examine the section up that sót, following the fortunes of the boundary (which we may call the Nahan-Siwalik boundary as named by Mr. Medlicott), and afterwards return to the Kosi R.

The boundary runs some way to the south of the sót itself, as the

Dhangari (Thunghully) sót. (19)

map shows; but a complete separation of the Nahan rocks from the conglomerate has not, by its means, been effected. Uplifted portions of the conglomerate to the north of the main mass are left running out along the hill-spurs, whilst the Nahans occupy the intervening stream-beds. There are thus numerous examples of the conglomerate lying unconformably upon the Nahans. The main mass of the conglomerate composing the western continuation of the Karaungia (Chinal) ridge approaches the faulted boundary with a dip of 15°, or 20° N. by E. except near the Kosi, where the dip is more N.E. The conglomerate on the uplift side has a lower dip in the same direction, scarcely ever exceeding 10°, which is also its average dip. The spurs which form the uplift expand out northwards, as they gently descend into the Dhangari and Sanguri (Shanguni) (20) sóts; and give rise to a number of sloping chaors, of triangular form, and of the annexed shape :—



This is a very common form of hill-slope in this country, both among the Siwalik conglomerate and the sand-rock stages, and occasionally in the Nahans, wherever the dip is down hill at moderately low angles. The larger four-inch maps show the structure perfectly, but the same cannot be said of the smaller scale map accompanying this memoir. This hill-structure is especially favourable to the growth of the sál tree. In the stream-beds between the chaors, and

extending some way up the sides of the gorges, the Nahan sandstones and shales present a very high dip of 70° or 80° immediately north of the fault, and lowering to 30° or 40° further away, the direction of dip being the same as in the conglomerates. There is thus a most manifest unconformability between the Siwalik conglomerates of the triangular chaors, and the Nahans of the stream-beds between them (see section V). The chaors and their composing conglomerates tail off in the bottom of the Dhangari and Sanguri sóts where they come to an end, partly by what is apparently a limit of deposition, and partly by another small fault. There is, at first sight, a suggestion of doubt as to whether the conglomerates here so manifestly overlying the Nahans can be of Siwalik age; but on mature deliberation I see no reason why they should not be. They are inclined at a low angle, and extend to such heights as to preclude their being of Recent age; not to mention the difficulty of finding any Recent river to account for them. The fact of their immediately overlying the Nahans unconformably indicates that there must have been considerable overlap of them above the sand-rock formation, inasmuch as the latter, on the other side of the ridge to the south, passes conformably beneath them. The high angle of dip in the Nahans denotes considerable disturbance of them prior to the depositing of the conglomerate above them.

At the same time, though I believe them to be of Upper Siwalik age, that is to say, continuously laid down with the regular main mass of the undoubted Siwalik conglomerate, it is certainly the case that they must represent the very uppermost beds of that age, and as such probably approach in point of time as near to the present day as they do to the age when the sand-rock was formed, on which they lie conformably. It does not seem to me to be in accordance with the natural laws of deposition to assume always a long interval of time between two sets of strata which are unconformable to one another, and to grudge a sufficiency of time for the deposition of two thick but conformable rock stages. I am inclined to think, on the contrary, that we have a better gauge in the thickness of the deposits themselves than in the fact of unconformability between

such; for who can say how long an age it takes to crush strata into a highly inclined position? It depends on causes which are quantitively less known than are those of deposition. I, therefore, urge that conformability, where the rocks attain great thickness, is a better proof of great age than unconformability, which merely indicates a break in deposition which need not always have been of immense duration.

The great extension of the fault between the conglomerates and the Nahans, and especially its passage in an easterly direction into a monoclinal fold (Dabka N.), as also its perfect parallelism to the strike of the beds, seem to point out that it belongs rather to the class of fold-faults than to those of normal dislocation. Still, there is no need to invoke a mighty sigmaflexure to do the work here: although horizontal pressure of the earth's crust must have had large lateral effect on the strata as a whole, it is probable that the immediate results were rather of an elevatory and depressive, than of a tangential, order in this locality. The fault, therefore, partakes of the nature of a vertical fault, slightly inversed; but it cannot have been due to a mere shrinkage, or to local accidents in the earth's crust, as is the case with an ordinary fault: rather, it must have been due to a larger movement of the mountain mass. Further on, when speaking of the Pátli dún, I shall have additional reasons to put forward in support of this.

Kosi R.

Returning to the Kosi R. section, the Nahan sandstones continue (generally obscured in the actual river-bed by Recent gravels) up to Mohán. One and a half miles north of that place the main boundary fault is reached and the Himalayan rocks set in. Between Mohán and the main boundary, however, there are several small chaors of nearly horizontal conglomerates which I am inclined to place with the uppermost Siwalik conglomerates. It is, however, possible that they belong to a slightly younger stage. This line of flat chaors continues, as will be seen from the map, westwards to join similar beds in the Rámganga R. at the junction of the Pandali Rau (21). From Mohán the Kosi bends away up stream E. S. E., along the strike of the rocks, keeping very near the main boundary. The latter finally cuts the river obliquely near

Okaldhúnga (22), whence it runs across the ridge in continuation of that north of the Kotah dún.

Rátapáni, Bijráni, Garjia and Sawaldeh sóts. (23)

The watershed of these four streams, and of other smaller ones in the vicinity, is the ridge of Siwalik conglomerate which I have mentioned as lying south of the Dhangari and Sanguri sóts. Over much of its length it has a steady N. by E. dip of about 20°. The southern aspect of this ridge is naturally a steep scarp as a rule, the conglomerate standing out very prominently in various tinted brick and ochre colours. The base of this scarp coincides with the base of the conglomerate, the sand-rock occupying all the country to the south of this down to the plains. These strata are well developed here, and show their many peculiarities and characteristics in a striking way. Having already embodied all the petrological detail concerning them in Chapter III, I shall not re-describe them here from that point of view. Just as takes place in the Chorpáni sót, the Siwalik conglomerate gradually merges into the underlying sand-rock by interbedding; the pebbly layers become thinner and scarcer, whilst the sand-rock increases in an inverse ratio. We have thus a complete unanimity of strike and dip, with complete proof of conformity in sequence between the Upper and Middle stages of the Siwalik series.

The low country into which we have now entered at the base of the conglomerate scarps is one of glistening sand hillocks: nowhere does it rise to any great height, and the banks of the streams, when they have water in them, are generally steep little cliffs, in which the various beds of sand and clay stand out well defined in their brilliant yellow colours. The knolls and small ravines and flat chaors are covered with more or less dense timber, but generally small in size. It is a habitat loved by the chital or spotted deer, and it is also a favourite retreat of tigers and wild elephants. Towards the plains there is a gentle rise in the height of the country, owing to a greater degree of hardness in the lower beds of the sand-rock stage. The various dips, as seen in the stream-beds which wander through this part, give an average of from 10° to 20° N.N.E. Down the lower reach of the Sawaldeh Rau it becomes

N.E. in places, though varying a good deal. There are a few banks of Recent gravels along the margin of this reach. There is no turning over of the dip towards the plains as we near them, but a continuous ascending series from them to the Nahan-Siwalik fault, which must represent the northern half of an anticlinal fold; the southern half having no hilly representative at all, probably on account of its early disappearance by reflexing and fold-faulting (see section V).

Denudation therefore has made much more impression on the country here than on that of the Kotah dún. The strata also show more lateral compression, and orography is not so entirely dependent on disturbance for its distinguishing features. The development of a slightly reversed fault between the Siwalik conglomerate and the Nahans, in place of the mere bend in the Kotah dún, is another point evincing greater compression. As compared with the lower reach of the Kosi, there is a return to the normal direction of disturbance, namely, along lines running W.N.W. and E.S.E. Nevertheless, in most of the small streams in this part near their debouchure on to the plains, there may be noticed a slight tendency of the direction of dip to vibrate on one side or the other of the normal direction, thus hinting at a disturbance, at right angles to the normal one, of the same nature as, but less intense than, that which produced the lateral shift and north and south folds in the Kosi.

Travelling in a westerly direction along the foot of the hills from the Sawaldeh Rau, we find numerous other streams flowing in much the same manner and generally in a southerly direction, named as in the margin. They take their rise also from the same ridge of Siwalik conglomerate and cut entirely across the sand-rock strata. The country they traverse is merely a continuation of that further to the east. It is lowest near the base of the conglomerate scarp, where the streams have widened their beds, and left some Recent gravel deposits in their vicinity. As they near the plains the dip increases in height, and with it the general

Khasaria (Ringola-ka) sót (24).
Dela N. (Jhada-ka-sót) (25).
Láldháng N. with its tributaries the Heri (Haili) Rau, the Súk Rau and the Choti Koti Rau (Jumnu gádh) (26).
Koti Rau with its tributaries the two Maunpani sóts.

level of the ground. Near their origin the streams cut through conglomerates dipping 20° N.N.E. This lowers a little to 15° or 10° in the sand-rock, which, as before, sets in gradually by interstratification with the conglomerate. Towards the plains the several minor streams unite into one gorge, where the dip is about 25° or 30° in the same general direction. There is also an accompanying hardening of the beds southwards, though the rock has still no title to be called a sandstone.

All the features of the sand-rock stage are now laid bare in very beautiful and perfect sections, illustrating the sequence and variations described under the heading of Petrology (Chapter III). Where the streams empty themselves into the plains, there is usually a well-marked vibration of the direction of dip on each side of the normal direction, as alluded to in the last paragraph. There is also no southerly dip of the strata at the margin of the hills: no preservation of the south portion of the anticlinal or middle limb of a sigmaflexure.

The great uniformity in the lie of the rocks in this part is reflected in the surface features. Standing on the conglomerate ridge between Barsóti and Láldháng, one looks down southwards into the country drained by the afore-mentioned streams, and the eye can grasp nothing except a broken and disturbed sea of jungle. The streams are too much shut in and too winding to be made out from this position. There are no lofty peaks or marked ridges to catch the eye: the whole is so alike, that it is as impossible to individualise any hill as it is to distinguish each wave in a wide ocean. Only, when looking along the strike of the more lofty portion near the plains, can one see the regular dip of the strata N.N.E., a structure which relieves the monotonous maze of hillocks to a certain extent. Northwards from the conglomerate water-shed one looks down a long series of side-spurs of the conglomerate, expanding into triangular chaors as they near the Rámganga R. Turning our gaze more in the direction of the Pátli dún, we may see these chaors approaching one another and levelling out more and more to form its southern slopes.

Before going on to describe this dún, I must give a few details

about the Nahan band, as it is exposed in the Rámganga R. north of Garral (Gurrul) (27). It represents the same set of beds as extend east into the bed of the Kosi; but whereas in the latter river they are obscured by gravels, in the more gorge-like Rámganga and in the Mandál R. (Mundal) (28) they are well seen. Generally speaking, it is much more difficult to get a reliable section through the Nahan beds than through the Upper and Middle Siwaliks; for their composition does not lend itself so much to observation as that of the two higher Siwalik stages: it very seldom weathers into the same cliff-like sections along the streams. In this case, however, there is a fairly good section along much of the river-bed.

Rámganga R. (Ramgunga).

Commencing near Barsóti on the Rámganga, the first beds of the Nahans met with north of the Nahan-Siwalik boundary are dipping nearly due north at 70°. Travelling up the river this is seen to lower to 30°. Near Garral, where the Sanguri sót joins the river, the dip is 60° in the same direction, although a little to the south of this it is 40° and 45° W.N.W. and N.W. For half a mile north of Garral there is an absence of good exposures, and then there is a solitary dip of 45° S.E. immediately followed by 60° N.E. The N.W. and S.E. dips just mentioned indicate a little irresolution in the normal dip, owing probably to cross-flexuring along the river-bed. It is a cross-flexuring which has tended in addition to widen the river-bed near Garral, and which, in its position at the south margin of these Nahan rocks, holds a similar place in the Nahan zone to the cross flexures in the Kosi and other streams at the south margin of the Upper and Middle Siwalik zones. Thus early we begin to see an homology between the behaviour of the latter zone with regard to the Recent deposits of the plains, and the behaviour of the Nahan zone with regard to it—a point to be borne in mind in view of future discussion. A little further on up stream we appear to pass over a synclinal; for the dip changes to S.S.W. at 80° and 70° which continues for some way. We next appear to pass over an anticlinal, the dip becoming 70° N.N.E. This gradually increases to the vertical. At the junction with the

Mandál R. the dips become 70° S.S.W. once more, indicating that a synclinal has again been crossed. The last mentioned dip continues up the Mandál R. as far as the Khakasgadi sót; when the beds become vertical once more, and then fall by degrees to 50° N.N.E. at the main boundary fault, which coincides with the great turn of the Mandál E.S.E. If we plot the dips, as in section V, and add the flexures as shown by the dotted lines, we get a general idea of the crushing to which the strata have been subjected. We see that, whilst to the south near the Siwalik conglomerate there is a wide synclinal with a rather flat southern limb, the ensuing anticlinal and synclinal to the north become much more closely packed together, and finally inverted. This presumes more intense crushing as the main boundary is reached. The strata north of the main boundary fault are Himalayan rocks, quartzites, &c., which curiously mimic in outward appearance the sandstone of the Nahan stage. An inspection by eye alone would scarcely enable any one to pick out the Nahan from the Himalayan rocks; but when the hammer is brought into play the great difference in the hardness and metamorphism makes the dissimilarity sufficiently conspicuous.

If we follow along the Rámganga itself from the point where the Mandál R. joins it, we have much the same sort of thing, namely, steep reversed dips in the Nahans and a reversed fault separating them from the Himalayan rocks. The latter, however, a little way from the fault, shew much more evident signs of crushing than the Nahans; so that we have a still closer set of folds than before.

In concluding the description of this part of the Sub-Himalayan zone between the Kotah and Pátli dúns, it is necessary once more to draw particular attention to the distinctive characteristics of the three sets of rocks composing it. The Siwalik conglomerate does not form the same flat plateaux that we found it to do in the Kotah dún, but it has a marked though gentle inclination to the north. Nevertheless, it is still free from complications, such as folding inversions, &c. The same remarks apply to the rocks of the Middle Siwalik stage: only near the plainward edge of the hills do they even acquire an angle of

dip amounting to 40°. At the same time, the single great flexure, into which the Upper and Middle Siwaliks are thrown, indicates earth movements and subsequent denudation on a scale much above that of the Kotah dún.

The Nahan sandstones, on the other hand, lie in an elevated zone by themselves, and are marked unmistakeably by their greater hardness and jointed appearance, by their being folded into several flexures with resulting dips of 70°, 80°, and 90°, and by inversion at the main boundary fault. They have thus a more ancient appearance than the rocks of either of the other stages, and show signs of lateral compression of greater intensity than has influenced the latter in the same area. In this respect they bear the same relation to the Upper and Middle Siwaliks that the Himalayan rocks bear to them. We see also that this contrast is most probably due to the difference in the lengths of time in which each formation has been subjected to mountain-forming and indurating causes.

It is essential to bear this in mind when considering the date of the upheaval of the Himalaya as a whole; for, so long as local sections show these different amounts of compression in neighbouring zones of different age, we shall not fall into the error of dating the whole of the Himalayan disturbance from late Tertiary times, on the insufficient ground that in one locality the Siwalik conglomerate is vertically inclined.

A similar contrast to the above is of course very noticeable in the Kotah dún; but I forbore from pressing the point there, as the Middle Siwaliks were invisible, and the only real conclusion to be drawn would have been that the Nahan sandstone zone had been much more disturbed than the uppermost Siwalik conglomerate.

There seems no room for any doubt whatever, therefore, that the disturbances which have affected the rock stages which have so far come under our cognisance cannot be imputed to one or more paroxysms acting in post-Siwalik times. It can with no truth be baldly stated that the "Siwaliks have been involved in the last colossal movements whereby the Himalayas have been upheaved." The

Siwalik series may not be spoken of in such a sweeping manner. They are like an old pile of buildings, that have been added to and restored during several historical periods, and that show several styles of architecture; so that, neither in the material, nor in the workmanship, can it be said that they are of one rock, or erected in one age.

THE PÁTLI DÚN.

Under this heading I propose to describe the country which lies in the Sub-Himalayan zone between the parts already disposed of, on the one hand, and the Peláni R. and lower reaches of the Rámganga on the other. This will include the Pátli dún itself. The latter is the largest of the dúns on this side of the Dehra dún. It is of a somewhat crescent shape, with the concave side facing south. It consists partly of the Recent, and sub-Recent river-bed of the Rámganga, which has deposited immense terraces of gravels at different heights, and partly of the low slopes of the Siwalik conglomerate which run up into the hills between the Pátli dún and the Pathair (Puthur) páni (29). It has no definite orographical commencement on the eastern side, but is simply an expansion of the ordinary bed of the Rámganga. Its western side is also somewhat indefinite as it merges into the Sona N. On the north it is pretty distinctly marked off by the river itself, which flows at the foot of a low fault-scarp. On the south it imperceptibly ascends into the slopes of the hills in that direction.

It is one of the most beautiful spots that the north-west provinces of India can boast. It is undisfigured by villages and bazars. A solitary forest bungalow, or chowki, is all that breaks the magnificent monotony of its billowy forests and grass-grown alluvial flats. But to imagine that here we are in the presence of a real bit of virgin country would be a mistake; many of the river terraces were once cultivated, and the sites of old fields can still be met with. These forests are in every sense a Government preserve; so that their richness in tree and jungle is due to the exclusion of agricultur-

ists and villagers; the establishment of numerous safeguards against loss by fire and axe; and the destruction of useless kinds of timber; not to mention other minutiæ of forestry which have helped to bring the forests to their present flourishing condition.

How the geology of to-day links itself with that of former ages, and how the present time is but a moment of the immeasurable past, and may in future ages come to be regarded rather as a portion of a continuous geological cycle in this region, is very well illustrated in the Recent and sub-Recent gravel deposits of the Rámganga. During the dry rainless season of the year the waters of this river are seen to form a narrow stream in a wide bed of glistening white pebbles, which marks its expansion in the monsoon, or its periodical changes of the last few years. Next, there are slightly elevated islands or banks of still older gravel which are now in the process of being cut through by the river, and which to some extent have become clothed with vegetation of young sissoo (shisham) and khair, with débris of broken drift-wood, dead trunks and tangled sprawling tree roots. Above these, rising well out of the river-bed, we see still older terraces, spreading in long flat steps one above another over most of the level portions of the dún. They are somewhat covered with soil, and support a dense grass jungle in which a tiger is as easily hidden as a grasshopper among the shoots of a well-kept lawn. Still higher slope the uppermost Siwalik conglomerates, or slightly coherent gravels, gently inclined to the north and flattening out under the gravels; but marking as plainly as the present river deposits the former existence in this locality of a river, which we can only regard as the direct parent of the Rámganga. Looking back in imagination through the ages involved in the accumulation of this sediment, we see an evolution from past conditions into present, as plainly stamped on the features of the earth as we do when we trace back the existing forms of life, the elephants, carnivores, and ungulata, which to-day swarm in these jungles, into their ancestral forms lying embedded in these very deposits.

Mr. A. R. Wallace, in his fascinating book on the Malay Archi-

pelago, described the great influence exerted by the sharp though marked geographical line of division (Wallace's line) between those islands of the Archipelago which belong to the ancient Asiatic continent and those which belong to the Australian continent, in keeping distinct the fauna (especially birds and mammals) of these two great zoological divisions of the earth in later geological and Recent times.

We have here among the upper members of the Sub-Himalayan formations a converse order of phenomena ; the unbroken sequence of deposits, that is, the merging of past geological into Recent deposits has carried with it a coherent chain of like forms, so that the same type of animals exist now in this part of the earth (though greatly reduced in the numbers of their genera and species) as existed in the remoter ages of the Siwalik period.

The present section of the Sub-Himalayan region is wider than any we shall have to consider in this work. To the north of the dún proper, there is a Nahan sandstone zone, a continuation without break of the Nahan beds to the north of the last described section. The slopes of the conglomerate south of the dún are similarly merely a continuation of those which form the range to the south of the Sanguri sót ; and so is the sand-rock zone south of it a continuation of the sand-rock zone described above. But the plainward edge of the hills shows a change in this locality. The sand-rock hardens by insensible degrees, and takes upon itself features which ultimately blend with those of the Nahan sandstone : in other words, we have the sand-rock passing down into the Nahans ; so that the latter now abut against the plains. In the petrology of the sand-rock and Nahan stages I have already indicated this passage, but without proof. The present and other sections show unmistakeably that such a passage does really exist. The likelihood of this was foreshadowed by Cautley (Fauna Sivalensis) on fossil evidence, collected further north-west in the beds near the town of Nahan, and has been discussed by Mr. Medlicott (Mem. III, G.S.I., pp. 105, 106). Later on Ishall go a little more fully into the subject of the consequences which follow on a

recognition of its truth. With this passage a greater disturbance of the beds ensues; they are inclined at higher angles, and their harder nature makes them stand out into more prominent hills than heretofore. But, besides this introduction of Nahans at the south edge of the section, we have a corresponding introduction of more of the sand-rock stage, in a synclinal with faulting, among what has hitherto remained a Nahan zone, to the north of the Pátli dún. In the Peláni R. this fresh appearance of them is well displayed, and will be described presently. We have thus an ever-increasing complexity in the strata as we travel westward along the Sub-Himalayan region. In place of the two zones at the east end of the Kotah dún, and the three in the Kosi R., we have now six zones arranged in the following order:—

N.
Nahan.
....
Sand-rock.
Nahan.
....
Siwalik conglomerate.
Sand-rock.
Nahan.
S.

These six stratigraphical zones may be grouped into three disturbance zones, as indicated by the dotted lines, which represent fold faults.

But not even here does the complexity end; for, if we cross the main boundary fault, we find the flexures into which the Himalayan rocks have been thrown involving with them representatives of the lowest Tertiary, namely, the nummulitics, and also of mesozoic strata in long narrow outcrops. At the conclusion, therefore, of the description of the Pátli dún I shall give a particular account of the section along the Peláni R. and the lower part of the Rámganga; in order to illustrate, by means of the very clear natural section there exposed (see section VI), the relations of the Sub-Himalayan zones among themselves, also their relation to the nummulitic and mesozoic zones, and finally the relations of all the foregoing to the older Hima-

layan zone. This cannot be considered to be beyond the scope of this memoir; for, as all knowledge is relative, we may not be said to possess a thorough mental grasp of the Sub-Himalayan zone, unless we study it not only in its own relations but also in connection with the older rocks in contact with it.

Kiláni sót. (30)

This sót is a little east of Jinti Rau trigonometrical station, and cuts across the Nahan zone north-east of the Pátli dún. There are no very good rock exposures, but such as there are give a W.N.W.—E.S.E. strike—the normal Himalayan strike. The dips are sometimes high and sometimes low, in a general N.N.E. direction. It is impossible to say whether these represent a uniformly ascending series or not: most probably not, however, and what we really have is a few closely packed and probably inversed folds, something similar to those in the Rámganga above Garral. The south edge of the Nahan zone in this locality coincides with the river bed, and also with the strike of the rocks, that is to say, it lies W.N.W. and E.S.E., but when the Delidúnga and Gaujera Raus are reached there is a noticeable change.

Gaujera (Goajada) Rau. (31)

This stream cuts across the greater part of the Nahan zone in a diagonal direction. In its lower part it is named the Delidúnga Rau on the maps of the Forest Survey. It rises in the higher ridge overlooking Jhirt, in the Mandál valley. This ridge, in its main features, is a synclinal; but, as the exposures on the north face are few and rare, it is possible that there may be a N.N.E. inversion abutting against the main boundary fault, as is the case lower down in the Mandál near where it joins the Rámganga, and as will be found in the Peláni R. Still, generally, it is a steep synclinal with dips of 30° and 40° S.S.W. on the north face, and with opposite dips on the south face. The latter dips continue down from the ridge until the bed of the Gaujera stream is reached, and increase in height up to 60°, 70°, and 80°, verticality being reached finally. About half a mile from the ridge a sharp anticlinal fold comes in, and the dip turns over towards the S.S.W.

again, the amount of dip being high as before. The direction of dip now becomes gradually due south, and, ultimately, when half a mile E.N.E. of Simal parao, east of south; and the road then follows the stream bed along the axis of another synclinal. The brown sandstones of the Nahans are here varied by a large amount of purple and chocolate coloured shales, which indicate the proximity of the base of the stage. The dips on each side of the synclinal axis are high, at angles of 60°, 70°, and 80°. At the point where the Delidúnga (32) is joined, the change in the strike has become even more pronounced, the dips now being N.W. and S.E. on each side of the axis. The lower parts of the Delidúnga, where it opens into the Pátli dún, are not very well exposed; but there seems to be some uncertainty of dip owing to a flattening out with faulting which brings in younger Nahans to the south. It is to be noticed that, coinciding with the change in the strike of the Nahan beds, from W.N.W.—E.S.E. to W.S.W.—E.N.E., the southern edge of the Nahans changes in the same way. We thus have the north-west portion of the Pátli dún bounded by low Nahan sandstone cliffs, which take a direction W.S.W.—E.N.E. The Pátli dún, therefore, owes its northern convexity to the oblique meeting of these two directions of strike, and to the strike faults which accompany them. At the same time, as a result of the change of strike, there ensues a greater widening of the Nahan zone towards the west: a spreading out of it, and flattening out of the dips, which allows the sand-rock stage, as already stated, to make a second appearance among what has hitherto been exclusively a Nahan zone.

Pátli (Patlee) dún.

If we now turn our attention to the southern slopes of the Pátli dún, we observe that the Siwalik conglomerate which forms them has no corresponding change of dip and strike. Its southern boundary keeps an unflinching direction W.N.W.—E.S.E.; and the dips both at the west end of the low range, and further east, can be seen by the maps to be N.N.E. at angles varying between 10° and 20°. The sand-rock stage, which comes conformably beneath the conglomerate, also has the same

direction of dip in the Pathair páni and its numerous tributaries. In the Rámganga, however, the sand-rock evinces a certain amount of yielding to the new direction of strike, its strike becoming east and west, and the dip directly towards the north. The consequence of the Siwalik conglomerate not having shared in the change of strike which is so manifest in the Nahans, is that the former become nipped out by degrees (with accompanying faulting) in a westerly direction against the latter. Along with the nipping out of the conglomerate ensues the extinction of the dún in the same direction.

The features of the Pátli dún, therefore, as were those of the Kotah dún, are directly dependent on the mode of disturbance of the strata. Its wide level expanse is a result of the low dip of the Siwalik conglomerate, of its regularity, and of its freedom from folds and flexures. Its abrupt termination on the north, and its westward extinction, are in like manner but the expression on the surface of the earth of disturbances in the crust. Thus, although we are entering on a more complicated arrangement of the strata as we travel west, it is still as true as ever that the youngest rocks show their internal character in a marked way by the tenor of their outward features.

The lower reaches of the Rámganga and the Peláni (Palaine) R.

I now turn to the Rámganga in its lower reaches, and the Peláni R. These two form one continuous section across the Sub-Himalayan region (see section VI). The Rámganga, where it issues on to the plains, partakes of the nature of a deep gorge with very steep sandstone cliffs on the east bank. For about 1½ miles this gorge is nearly north and south, and is the outward sign of the greater hardness of the Nahan sandstone through which the river is cutting its way (for, as already mentioned, the Nahans have now appeared conformably underneath the sand-rock stage at the plainward edge of the hills). No one gazing up-stream between the portals of dark sandstone would ever guess that in the course of a few miles the banks would flatten out and the river-bed widen into the picturesque upland valley of the dún. The river here, in cutting through this plainward hardened band, has had to cut straight and with set purpose. The

elevation of the rock into an inclined position of 40° has given no time to the river to meander and widen out its bed. With its action sharpened by resistance, the river has had to cut as it were against time, else the barrier of rock would have risen against it and driven it to find an exit by some other track, just as it had already been turned far out of its direct course to the plains by the rising barrier of strata further east, alluded to in Chapter II. But in the dún, the flatter arrangement of the beds marks a less energetic elevation of them: there was less necessity for the river to cut a vertical track, and so it had leisure to wander capriciously, changing its bed again and again, and spending horizontally the energy that lower down was acting vertically. It is necessary to bear in mind this law of river action, when contemplating the formation of dúns; for, though their main features and boundaries are exclusively due to the original moulding of the earth's crust by a lateral compression, the whole is subsequently softened, and brought to a more general level by the secondary action of the river in changing its bed and by reason of its sinuous course.

The plainward zone of Nahans begins as fairly hard, yellow sandstones and shales of the ordinary type and with concretions in their upper layers. The dip is 30° to 45° N.E., increasing in steepness as we reach the first important bend in the river. As we still ascend, following the forest road to Boksár, the sandstone gradually becomes less hard and merges imperceptibly into the sand-rock stage. About $1\frac{3}{4}$ miles above Kálagarh the sand-rock sets in with certainty. There is no change of dip, which continues N.E. and N.N.E. at from 38° to 40°. At the junction with the Sona N. the rock has become thoroughly of the sand-rock type, so soft and friable as to be unmistakeable. The orography in this neighbourhood, especially near the boundary between the sand-rock and the Nahans, is remarkable for the great prevalence of the triangular wedges of strata which form the hill spurs. They rise one behind the other, displaying in plan a set of contours as shown in fig. 1, and in profile as shewn in fig. 2.

Fi . 1.

Fig. 2.

They resemble a gigantic staircase that has suffered some convulsion of nature. Beyond the Sona N. in a N.N.E. direction the river shows no exposures for some way, and widens out into the alluvial flats which form the western termination of the dún. Near Boksár, however, low cliffs washed by the river still give exposures of the sand-rock, but the dip is more nearly due north than before at a uniform angle of 20°. Suddenly, nearly a mile N.N.W. of Boksár, they cease altogether, a fault intervenes between them and the Siwalik conglomerate, and we then enter upon one of the most striking features in the structural geology of the Sub-Himalaya. The fault, however, between the conglomerate and the sand-rock is probably of no great throw in relation to others that we are about to examine, and has taken place along a synclinal bend. It has been sufficient, however, to cause the thin band of conglomerate to vanish on the south side of it It is doubtless a mere local fracture and does not extend far in either direction. On the north side of this fault the Siwalik conglomerate forms the north limb of a compressed synclinal fold, dipping generally 50° S.S.E. Its outcrop in the river section is about half a mile across, showing the attenuated condition to which it has been reduced by the nipping-out process already referred to, though, as will be shewn later on, the conglomerate was probably never very thick west of the Pátli dún. The northern boundary of the conglomerate is a reversed fault, near which the previously mentioned

dip of 50° S.S.E. gradually increases up to 90°, and then becomes inverted 40° in the opposite direction at the position of the fault (see section VI). North of the reversed fault, lowermost Nahan sandstones, with a great display of purple shales, and much crushed, dip north at high angles. It is of the utmost importance to get a right conception of the relation of the three rock stages to one another in this locality. If we examine the horizontal section (No. VI) we shall see that, for the sake of simplicity, the southernmost fault may be neglected. What we have to consider is the reversed fault separating the Siwalik conglomerate from the Nahans. It is apparent at a glance that this Nahan-Siwalik boundary is not the simple thing we saw it to be south of the Sanguri sót, represented in section V. In the latter section there are to the north of the fault uppermost Siwalik conglomerates lying in marked unconformability upon lowermost Nahans; from which the inference was drawn that the lower part of the conglomerate, and the whole of the sand-rock stage, had been overlapped as if deposited against a shelving slope of Nahans. That is to say, the position of the fault had to be regarded as a limit of deposition for the Middle and most of the Upper Siwalik stages. The case in the present section, however, is different. From the fact that to the north of the reversed fault, the Nahans are again covered conformably by the sand-rock at Gutua gádh, we cannot regard the fault as a limit of deposition for that rock stage. It must have once spread over the high Nahan ridge, continuously, from what is now the west end of the Pátli dún into connection with the corresponding rock higher up in the Pelâni R. Of course we might assume that the Nahan ridge was a ridge in part when the sand-rock was deposited, and that the latter was laid down synchronously on each side of it; but this would be a gratuitous assumption, and not borne out by sections across the same ridge further north-west. If we look at section VII across the Sona N. near Dhánsi chaor, we find no signs of the sand-rock thinning out or overlapping itself against a cliff of Nahan sandstone; on the contrary, the northern half of the inverted synclinal (which at the same time is

part of the middle limb of a sigma-flexure into which the sand-rock is thrown) is preserved almost in its entirety: the thickness north of the axis of the fold is almost equal to that on the south; and the nature of the rock changes by becoming harder and more Nahan-like as we diverge both north and south from that axis. The structure is as far removed as possible from that in section V; and warrants us in believing that, immediately south of the reversed fault in the Rámganga, the sand-rock is of proportionate thickness beneath the thin band of conglomerate, and *ergo* that, immediately north of the fault, a similar thickness has been denuded away from the top of the Nahan ridge.

The only question that seems to me to need considering is whether we are to regard the position in the Rámganga as *entirely* a modification by further faulting of that in the Sona N., or whether we may accept a compromise between that and the position as shown in section V. The two extremes will be seen to be exactly equivalent to those drawn by Mr. Medlicott across the Una dún and the west end of the Pinjor dún respectively.[1] I think on the whole the position in question must be regarded as more nearly agreeing with that in the Sona N. We must picture a sigma-flexure, as in the Sona N. section, suffering further compression and tearing along the middle limb; resulting ultimately in the formation of a thrust-plane, and almost complete obliteration of the middle limb. The magnitude of the result is, however, somewhat startling. The uppermost beds of the sand-rock, or the lowermost beds of the Siwalik conglomerate, on one side of the reversed fault lie at the same height as the visible base of the Nahans on the other side. If we go back along the section to the point where the Nahan sandstone band, north of Kálagarh, dips conformably below the sand-rock, and carry an imaginary junction line forward *beneath* the section up to the reversed fault continued downwards, and if we then go forward along the section to where the Nahans are again covered by the sand-rock, at Gutua gádh, (33) and carry the junction line backward *above* the section up to the reversed fault, we shall find the two

[1] Manual of the Geology of India, p. 550.

points where they cut the fault separated by an enormous gap, representing a distance along the fault of about 11,880 feet, or $2\frac{1}{4}$ miles, which is a vertical distance of about 6,380 feet, or $1\frac{5}{8}$ miles. The enormous compression which the strata must have suffered, to enable the northern portion to work up over the southern, in this remarkable way, has left considerable traces behind it, in the crushed and shattered condition of the lowest Nahans, well seen at the junction of the Peláni R. with the Rámganga.

In an E.N.E. direction the reversed fault follows the line of cliffs which lie to the north-west of the Pátli dún; all of which cliff-sections exhibit conspicuous crushing. At the most northerly point of the dún where the strike changes, we find the continuation of the fault (obscured by Recent gravels) changing also and taking an E.S.E. direction to the south of the Sanguri sót. It is manifest that this line of fold-faulting along its course, from near Dhánsi chaor up to the Kosi R., culminated in a maximum break in the Rámganga; and that it dies away to a certain extent in each of the opposite directions. To the E.S.E., beyond the Kosi, in the Dabka R., we have already seen that it becomes a mere monoclinal fold, and later we shall see what becomes of it in the opposite direction.

Our section now leaves the Rámganga, and we enter the gorge which the Peláni R. has cut out through the flexured and elevated Nahan sandstone. Dips of 50° N. are first seen in the crumpled and shattered sandstones and shales. These dips increase to 90°, and we pass over a sharp synclinal. Then follows an anticlinal with axis along the westward bend of the river, and north of this steady dips N.N.E. continue for a long distance up the Peláni R. or Túmriah (Toomreeah) R (34). The amount of dip lowers from 70° to 50° in an ascending series of sandstones, which become less hard and less jointed as they merge into the sand-rock. At the junction of the Gutua (Gutu) gádh the sand-rock stage is fairly represented. The change is coincident with a lowering of the surface of the country, with a slight lowering of the angle of dip which now continues between 50° and 40° N.N.E., and with a change in the character of the river-

bed. The latter now widens out, horizontal chaors and alluvial flats become more common, and the river winds to a greater extent than before. So abundant are the natural sections in the river cliffs that all the petrological characteristics of the two rock stages, in this section along the Peláni, are passed in review like an open book of which not a page has been effaced.

As will be seen by the map and the horizontal section VI, the centre of the synclinal in the sand-rock stage is broken by a slight vertical fault, of no constructive importance, it being a mere fracture of the same kind as that dividing the sand-rock from the Siwalik conglomerate further south. North of it higher dips in the opposite direction set in amongst beds of slightly higher horizon than those to the south of it. They soon become vertical and then inverted against the next reversed fault at Halduwala. The appearance of these sands, clays and loams, softly tinted of an ochre, brown, and purple colour, and in an absolutely vertical position, is a strange sight to one accustomed to the gentle undulations of the Tertiary strata in England. Slates and schists we are accustomed to see in highly inclined positions, but to witness these sediments of yesterday (geologically speaking) in so incongruous a position fills one with wonder. We follow their vertical lines into the air above the level cliff-top, but we can never conceive in their entirety the great piles of material that have vanished by denudation since the Middle Siwalik age.

The fault at Halduwala (35) is of the same nature, structurally, as the previous reversed fault, though it does not appear to be of so great magnitude. Beds moderately low down in the sand-rock stage on the south of it are in contact with lowermost Nahans on the north, and the change from one to the other is sufficiently striking to the eye and hammer; though of course not so vivid as that between the Siwalik conglomerate and the Nahans in the Rámganga. The fault, therefore, indicates a similar compression of the strata resulting first in a monoclinal fold, then a sigma-flexure, and then a tearing along the middle limb of the sigma-flexure and production of a reversed fault. To-

wards the south-east in the direction of the Gaujera Rau this fault appears to die out.

The sand-rock stage in the Pelâni is now left behind. Nothing but Nahan sandstone intervenes between this point and the main boundary. The folds into which the Nahans are thrown, however, can be better seen in the section than described in words. Generally the result is a great synclinal, with lesser secondary folds borne on it. At the centre of the section the rock is evidently very near the top of the Nahan stage, from the greater softness of the rock and its appearance of being about to pass into the sand-rock stage. At the main boundary fault the strata are neither uppermost nor lowermost Nahans, but their horizon seems to be intermediate. A marked feature of this Nahan zone is the greater folding to which the strata have been subjected, together with the inverted state of many of the folds, which gives an appearance at first as if the whole were an ascending series in one direction. In many respects it can be seen to be analogous, in its folds, to the structure already noticed in the Gaujera and Delidúnga Raus.

We have now reached the main boundary fault once more. The Pelâni R. cuts through a steeper and higher set of hills than heretofore, which marks the in-coming of the mesozoic, nummulitic and Himalayan zones. As being a very illustrative section, therefore, I shall continue the description up the Pelâni R.; for, although I shall thereby be trenching somewhat on a subject foreign to the matter of this memoir, I hope the better to exhibit the true status of the Sub-Himalayan zone by comparing it with those older zones.

A few remarks may be made upon the surface features of the country to the north of the main boundary. The change from the low-lying ground of the Sub-Himalaya to the much higher ranges to the north is very apparent. We lose for ever those flat and undulating dúns and chaors which so characterise the zone of younger formations. With the change in the nature of the rock there follows a change in that of the soil, and in the vegetable products of the soil. The jungles lose their depth and vastness, and their tropical characteristics seem to give way with magical abruptness.

No longer can it be said with truth that the surface features have much dependency on the lie of the rocks. Denudation alone, as embodied in the vermicular tracks of the streams, has laid out hills and valleys according to its own caprice; and especially is this the case when the schistose group of strata is definitely entered upon. A homogeneity of composition, and an unknown amount of reflexing and contortion, doubtless dating far back in the history of the schists, has caused all inequalities due to simple disturbance to be effectively masked by sub-aerial influences. Along with the change in the vegetation, and in the surface of the ground, the denizens of the jungles become scarcer and of a different stamp. The spotted deer (*Axis*) utterly ceases with the dúns and chaors, on whose flat surfaces they can alone live naturally. The elephant, as if baffled by a charm, never passes beyond the ridge which marks the line of the main boundary. In the same way many other examples of large game equally seem to cease to thrive among the higher hills, or if they do pass into them it is from some artificial reason and not in accordance with their normal instincts. Tigers, for instance, are known to travel up to great heights, following herds of buffaloes seeking pasture in the more elevated region during the hot months; but in this light they may be regarded as semi-domesticated animals.

Indeed, on passing into the higher Himalaya, the change is an all-round one. The reserved forests as a rule cease, or, if they extend a short distance, they never pass beyond the zones of nummulitic and mesozoic age. The country is much barer to the north. The associations, climate, and inhabitants are very different. With the absence of reserved forests a quiet domesticity steals over the landscape; the hillsides become covered with small villages, each with its little plot of terraced fields and straggling uncared-for jungle round about. To the traveller the change means a great deal; he must reorganise his camp equipment, exchanging camels or elephants for coolies or mules; because, not only is he ascending slowly but surely into a more temperate climate, but deeper ravines and steeper hill-

slopes, void of good roads, will meet him every day in place of the gentler slopes and more softened country which he is leaving behind.

At the outset of this subject some difficulties appear. There are no such good natural sections among the rocks of the zones we are now entering upon as there were in the Sub-Himalayan zone. Although the Peláni R. is better off in this respect than many others which flow through corresponding country, still, owing to the nature of the rocks, such continuous sections cannot often be found. The geologist must gird up his loins and go to work with all his observing faculties awake if he would obtain a rational result.

I have, in another place,[1] partly described the geology of the Himalayan zone in this neighbourhood as divisible, for the purposes of classification, into an inner and outer set of formations; the inner being composed of schists and other crystalline rocks; and the outer in ascending order, of a slate and volcanic breccia series, a massive limestone, a lower and upper Tál (mesozoic) series, and a thin band of nummulitic rocks. To a stranger or novice in Himalayan geology (as I can testify by my own experience), the section we are now called upon to examine would be full of pit-falls and obstacles. As he advanced, step by step, tracing the geology as it would be provisionally laid down on a working map, he would be puzzled by a great similarity in the dips among different formations; so that less indurated appear to underlie more hardened, and less metamorphosed under more metamorphosed strata. No trace of strike faults or thrust planes would be manifest, as they are in the younger Tertiaries; no conspicuous crushing along junctions, nor apparent unconformability. True he would eventually be certain that some of the outer formations must be younger than the very metamorphosed schists in the Jhar (Thél) gádh (36), but he would be at a loss to fix the position of the stratigraphical hiatus. He would be further hampered by an appearance of passage from the uppermost nummulitics into the southern beds of the purple slate and volcanic breccia series; for the former have become much more hardened here than I have elsewhere seen them,

[1] Records, Geological Survey of India, Vol. XX, p. 26.

and no sharp break can be detected between them and the slates with which they have become welded as it were by a sustained pressure. That such a break must exist I have shewn in my previously quoted paper, by reference to a portion of the country further north-west, where the differences of metamorphism are more conspicuous. In detailing the section to follow, I shall again put forward a weight of argument, which must disprove what would otherwise be a somewhat fascinating, and on the surface of things plausible, theory, that the schistose series were, as their position seems to indicate, of really younger age than the nummulitics, above which they might be considered to lie in a great synclinal.

At the main boundary fault the bed of the Pelâni divides into two channels, and it is in the western of these that a junction section is exposed. The Nahan sandstone, fairly hardened, is seen to dip apparently N.N.E. at about 60° ; and above it, with merely a few inches of grey calcareous mudstone intervening, comes the massive limestone dipping also in the same direction, and with the same amount as the inverted Nahans. There is no crushing or disturbance of the rocks visible, though the hidden ground on both sides may contain examples of such crushing. No one, from the composed appearance of the rocks, would dream that there was a fault, much less a reversed fault or thrust-plane, along that plane of junction. And yet, looking forward along the section, we see, by reason of the appearance of mesozoic and nummulitic strata normally above the limestone, that the main boundary cannot be an inverted plane of natural deposition, even approximately. We see absolutely that immense faulting must have supervened.

For about a quarter of a mile north of the main boundary, the exposures of the massive limestone in the river section are not good. The banks are hidden by stalactites of calcareous tufa in dripping, mossy cliffs. There is next a short distance of massive limestone, and a few grey slates, dipping from 80° to 60° N.E. ; and then a purer band of the limestone. This rock is of the same nature as those repeatedly mentioned in my previous papers on the Himalaya, that is to say, it

is a dark grey-blue dolomitic limestone, with a few slaty bands; and altogether barren of fossils. The dip steepens a little towards its northern boundary, becoming between 80° and 90°. In the horizontal section, No. VI, which is drawn due north and south, the apparent dips are necessarily much less. The mesozoic Tál beds do not actually occur in the river section, owing to a cross-fault running nearly E.N.E.—W.S.W., the line of displacement in the river-bed being just such that the nummulitics on the north of the fault are in contact with the massive limestone on the south of it. The mapping here differs a little from that accompanying my paper in the Records.[1] Sufficient prominence there was not given to the fault in its westward extension; and the nummulitics are represented as being folded amongst the purple slates. I have since found out that what I took to be purple slates on the south of the nummulitics are really hardened beds of the latter stage, and that therefore their normal position is directly above the Tál beds, as is shown over the rest of my former map.

Although the Tál beds do not appear in the river section, they are prominently displayed on the two ridges on either side of the Peláni river. It was on the western of these that I first found the fossils which afterwards identified these beds with the original Tál beds of Mr. Medlicott, and gave their probable age as mesozoic. They are composed in this locality, as elsewhere, of a hard grit and sandstone with a few pebbly bands in their lower part, and of a calcareous grit or oolitic limestone, weathering an indigo-black colour in their upper part. In the latter the fossils were obtained. I can do no more here than refer to them thus briefly, as this memoir does not concern them directly. Besides which consideration, a better collection of the fossils must be obtained before any more definite geological horizon can be assigned to them. The dips in the Tál beds coincide very nearly with those in the massive limestone below, and the nummulitics above; that is to say, they are very steep, averaging between 70° and 80°, though in the horizontal section this

[1] Records, G. S. I., Vol. XX, p. 26.

is much reduced on account of the direction of the section being diagonal, and not at right angles, to the strike.

The nummulitics in the river-bed show a certain amount of purple shale associated with them, which in some instances is very difficult to distinguish from the purple slate series to the north. Generally, however, it may be laid down that the beds near the nummulitic calcareous layers are less hardened and slaty, more of a shale in fact, and they contain a sufficient amount of lime to effervesce slightly with acid. Among them two or more bands of grey nodular impure earthy limestone appear containing nummulites. In certain places on the ridges the nummulitics have also a sandy element, which occasionally weathers into a soft brownish sandy rock, very friable, in which casts of foraminifera and bivalves can be seen. It may be remarked here that generally on the ridges, away from the influence of the river, the strata have become softer, and can be more readily and sharply divided off from the purple slate series. This is not altogether due to the weathering of the rock in this more exposed position, but also to the selective action of the river, which has cut away all the softer portions of the beds, leaving only standing up in small cliffs on the visible section those portions which were sufficiently hard to offer a certain amount of resistance to the river action. River sections in very many cases give a better index of the structure (dip, sequence, &c.) of the rocks than of the finer differences of composition: the laving water cuts and moulds every rock to a much more uniform appearance than the slower action of sub-aërial agencies.

On the north edge of the nummulite-bearing calcareous layers, there is a doubtful zone of purple shales and purple grits, which sometimes seem to merge into slates; after which there come grey slates with wavy bedding, almost vertical and passing upwards into undoubted thorough-going slates of purple and greenish colour, and these in turn finally pass into the volcanic breccia. The grey and purple slates and breccia are almost vertical, and somewhat folded among themselves, no doubt, but it is difficult to say how exactly. The latter half of the purple slates and the southern half of the breccia

are perfectly vertical. Up the Jhar (Thél) gádh, however, we notice, after nearly a quarter of a mile of vertical breccia, a gradual lowering of the dip to 25°, and the in-coming apparently superposed on them of slightly schistose slates, which merge into definite schists, dipping at various angles N.N.E.

It will be seen from this description that there is a complete absence of reliable superposition between many of these strata. Their dips are nearly vertical, and their planes of junction often so obscured as to be unrecognisable as faults or unconformabilities, from a purely local examination. The slight tendency of all the members of the series to underlie towards the north at first pre-disposes the stranger to regard them as a real ascending series from the main boundary to the schists. The first step therefore in getting a right understanding of their real position is to dismiss this false impression.

That the nummulitics cannot be a calcareous portion of the purple slate series is sufficiently shown, I think, by analogy in the first place. In numerous other sections, as the map with my aforementioned paper will show, the nummulitics are dipping down against the schistose series direct, and are separated from the purple slates by a very great thickness of Tál and massive limestone. They are thus out of all relation with the purple slates and breccia, in a part of the country where the rocks are less disturbed than in the Peláni. But the most convincing argument is one deduced from the general lie of these rocks over the large area through which they have been traced. Everywhere along the southern face of the outer Himalaya, both as mapped by myself in Garhwál, by Mr. Medlicott in the Simla area, and by other workers, the nummulitics present but the aspect of a thin band or two of fossiliferous calcareous rocks enfolded with, or faulted against, slates or schists. Now the metamorphism which has affected those slates and schists, on the above supposition that the nummulitics are one with the slates and schists, obliterating their primitive structure, and developing in them schistosity, hardening them and sometimes cleaving them, has certainly destroyed all traces

of fossils, if fossils ever existed in them. On that supposition, therefore, how does it happen that the agents of metamorphism have worked over such great areas, and left such extraordinary linear oases of nummulite-bearing rocks near the outer margin of the hills? If we assume the metamorphism to be of the nature of all known metamorphism, that is to say, either regional or due to intrusions of igneous rocks, we cannot believe, considering the wide extent of country which has been metamorphosed, that any action of such nature would be able to cease along such abrupt lines as the necessities of the case would demand if the fossiliferous strata were only slightly altered portions of the same series. If, on the other hand, the schists be regarded not as metamorphic but as primitive (in a sense), the distinctness of the nummulitics needs no comment.

Perhaps I may be deemed to be exerting myself unnecessarily to demolish what may be thought by the reader to be an unwarranted belief; but from my own past experience I know how apt the mind is to neglect these larger and indirect results of reasoning over wide areas in favour of a local section showing an apparent passage. For instance, in the Peláni R. the lie of the two sets of strata is exceedingly similar. Through the zone of purple slates there stand out from the shingle of the river-bed, long, low quays of the thinly bedded rock with an almost vertical dip. Through the nummulitic zone identical quays of a thinly bedded rock with a high dip seem so palpably a continuation of those slates that the keenest geologist, if by chance he missed the fossil-bearing bands, would map them all as one.

But I have shown that, if our knowledge of the laws and conditions of metamorphism be not entirely a myth, this cannot be the case. The nummulitics, therefore, must be newer than the slates and schists, and therefore there must be a fault separating them from these rocks. Thus, in the Peláni R. section we have to place a fold-fault on the north side of the nummulitic band of strata, of at least 4,500 feet vertical throw; for the fault once being granted, there is then no reason for referring the purple slate and breccia series to any other horizon than one below the massive limestone, in conformity with

the results of observations made further west in Garhwál, where, as already stated, clearer sections show them to be in that position.

Having disposed of the principal difficulty by the interposition of a fault, we observe that between it and the main boundary there is merely a regular descending series, perfectly intelligible by itself, and needing no faults to explain it, except a slight cross-fault along the Peláni, which is of small structural importance. Thus, the massive limestone, the Tál, and the nummulitics form one block of formations, homogeneous from a structural point of view, and in their normal order; though there is most probably slight unconformability between certain of them. Throughout a very large area, indeed, the same three formations ever present the appearance of a regular sequence, their order always being the same. No fold-faults have ever been detected which would bring a younger one of these three formations in a position of dipping down against an older.

The remaining point to be considered is whether the schists in the Jhar gádh, and which occupy much of the higher ground to the north of that position, are really younger than the volcanic breccia and purple slate, above which they appear to lie; or whether here also is indicated a reversed fault. There is very little doubt that the latter is the correct supposition, and that the schists are really the oldest formation exposed in the section. In other parts of Garhwál, the purple slates and breccia, about whose striking identity there can be no doubt, are seen to normally underlie the massive limestone and the Tál beds in a series of symmetrical flexures without the interposition of the schists, which on the other hand lie in a higher central zone by themselves. By a similar reasoning to that advanced for the reversed fault between the nummulitics and the purple slate, we may therefore point with practical certainty to a reversed fault between the schists and the volcanic breccia.

We have now gone over the section in the Peláni step by step, perhaps more in illustration than in proof of the relations of the Sub-Himalayan system to the Himalayan groups. In this brief glimpse of the older rocks one cannot help assuming a good deal that it will

be my duty, I hope, later, to prove in a separate work; still I have endeavoured to make this section as complete in itself as possible, so that we may now note those few general laws that seem to hold with so steadfast a pertinacity in *all* the relations of the Sub-Himalayan zones among themselves and with respect to the Himalayan zones, and of which laws the Peláni R. offers so brilliant and striking a resumé.

In the first place, we cannot fail to be impressed by the aspect along this section of intense lateral crushing, no matter at present how or when originated. If the strata in the section, which is 19 miles long, were flattened out, so that the folds were annihilated and the faults allowed for, the section would be about 8 miles longer than before. In other words, since the beginning of these rocks, this portion of the earth's crust has been so compressed laterally as to take up at greatest only $\frac{11}{19}$ths of its former space. Perhaps the amount would be less than this could we but follow out the folds of the older rocks southwards beneath the Tertiary zone.

Secondly, the plications are sharper and more numerous in the older zones, and longer, more undulating, and less closely packed together in the younger.

Thirdly, reversed faults are common and normal faults scarce, and the former always hade N.N.E., or thereabouts, and are parallel to the strike of the rocks. These reversed faults are full of deep significance; they represent inversed middle limbs of sigma-flexures, often of great size, which have become reduced by traction and tearing to an apparently clean-cut fracture; and by their means we can mark out the section into disturbance blocks, or bands. Numbering the stratigraphical zones in order from the oldest upwards, and grouping them into disturbance bands as marked off by the dotted lines, we have as below:—

N.N.E.

Schistose group (1).

....

Slate and breccia series (2) and (3).

....

Nummulitics (6).
Tál (5).

Massive limestone (4).

....

Nahans (7).

....

Middle Siwalik sand-rock (8).
Nahans (7).

....

Siwalik conglomerate (9).
Middle Siwalik sand-rock (8).
Nahans (7).

S.S.W.

In all there are twelve stratigraphical zones, grouped into six disturbance zones.

Fourthly, each disturbance zone, except the purple slate and volcanic breccia, has its ascending order of rock stages at the surface from south to north; nowhere is there an ascending series of different stages dipping south; for such a position in this greatly crushed region is unstable. As soon as formed, it would tend to become vertical and then inversed by the ceaseless horizontal crush of the rocks; and then following on inversion would come the tearing along it (now become the middle limb of a sigma-flexure), and the final condition of a reversed fault. As a corollary to this, every formation, when its southern neighbour is younger than itself, is divided from it by a reversed fault; and, when its southern neighbour is older than itself, it is in normal superposition upon it. Only among the younger Siwaliks do we see, in an individual stratum, a normal dip to the south still left as evincing portions of a middle limb not entirely inverted or disseminated.

Fifthly, each disturbance zone is, considering the average age of its rock stages, older than the succeeding zone to the south; because each succeeding zone introduces a newer member than was previously present; this is shown in the table above by the numbered formations, a higher number and a higher average number coming in with each disturbance zone to the south. Should the present plainward edge of the hills be a reversed fault, it will in due order come to pass (when a further crushing of the margin of the hills has taken place)

that a still younger member will be then introduced with the new disturbance zone, namely, what are now the Bhábar gravels and alluvium of the Ganges valley.

Sixthly, I think we are entitled to consider it in the highest degree probable, amounting almost to certainty, that the five reversed faults cannot have been contemporaneously produced. I have laid especial stress on the part these faults play throughout the section, first, because of their magnitude, and, secondly, because of their undoubted connection with the flexures into which the earth's crust has been thrown. They are *de facto* the ultimate expression of a flexure, and, therefore, cannot be separated from the flexures of the strata between which they lie.

If then, as I have repeatedly insisted, the older zones show more folding than the younger zones, and if that is to be imputed to the longer intervals of time in which they have suffered compression (than which I see no other explanation), then we must also believe that the fold-fault between two older zones must be of remoter antiquity than a fold-fault between two younger zones. Thus, not only does each disturbance zone as we travel south exhibit a set of strata younger, as regards the mean time of its deposition in the form of sediment, but, also, each disturbance zone, from the point of view of its disturbance, must be regarded as a younger product than the zone immediately to the north of it. Therefore, *pari passu* with deposition of these sets of strata at the margin of the Himalaya, there has gone on a crushing and upheaval of their neighbour zones to the north, which has resulted in stranding them, periodically, one after the other, in the form of these disturbance bands; thereby adding, by an unconscious accretive evolution, fresh strata to the mountain mass as the ages rolled along.

CHOKAMB AND KOTRI DÚNS.

Surface features.

Under this heading I shall include the whole of the country between the Rámganga and Peláni rivers, on the one hand, and the Kho R. at Kotdwar (Kotdwara)

on the other. The Kho will be seen to mark a very great change in the geology of the Sub-Himalayan zone, inasmuch as everything younger than the Nahans will be found to cease there. The sand-rock and conglomerate bands we shall find gradually dying out, as the Sub-Himalaya narrow in that direction, by a somewhat abrupt northern bending of the plainward edge of the hills. The Chokamb and Kotri dúns, as they are called, do not by any means make up the whole of the country included within these boundaries: nor are they, in the strictest sense of the word, dúns at all; for there are no flat valley plateaux of any extent, moulded by Recent or sub-Recent rivers. They more nearly resemble much of the country to the west of Rámnagar, that is to say, their condition is that of an undulating diversity of small hillocks of rapidly weathering sand-rock material, whose summits all lie much about one level. They have thus a general resemblance to dúns, especially when they are considered in conjunction with the higher Nahan ridges, which shut them in on their north and south sides. They need, however, the Siwalik conglomerate as a superficial layer, dipping at low angles, or horizontal, to give them that plain-like unity of surface which is so characteristic of the Dehra, Pátli, and Kotah dúns. The low country through which the Pelání runs near its junction with the Mandálti R., and the similar tract through which the Sona N. winds, might, with equal propriety, be called dúns, for they present very much the same appearance, and only require a more complete encircling of the higher ridges to give them as doubtful a title.

With regard to the general features of the country and its flora, nothing need be said that has not already been remarked about the similar country to the west of Rámnagar. Everywhere dense jungle prevails, rising and falling in billowy irregular forms, which mount into steeper crested ridges in those places where the harder Nahan sandstone bands are present. A few temporary village communities of gold-washers thrive on the banks of the Sona N. during the rainy season, when the streams are in flood, and the glittering micaceous alluvial mud and sand spread in thick deposits with a modicum of the precious metal.

The Sona N. and Mandálti R. are longitudinal streams which follow the strike of the softer beds, whilst the corresponding ridges on either side of them are made up of the harder Nahan sandstone. The Kotri or Sanneh river (37) is a transverse stream flowing through the Chokamb and Kotri dúns.

Sona N.

The Sona N. (or "gold river" as the word signifies) joins the Rámganga a little below Boksár, and is separated from the plains by a well-marked ridge of Nahans, the direct continuation of the same band which is seen in the lowest reach of the Rámganga, and which has been already described. From henceforth this Nahan zone holds its own fronting the plains all the way up to Láldháng. There is nothing remarkable about it in this locality: its general lie being very much the same as in the Rámganga. The road from Kálu-Sháhid (Káloosyud) to Mota-Sál (38) exhibits a good section through the upper portion of it, which is dipping at angles of 40° and 35° N.N.E. or N.E. Its passage up into the sand-rock series also presents no new features; the line of junction as drawn on the map being seen to be nothing but a prolongation of the line which cuts the Rámganga. The sand-rock stage, in like manner, has no complications until the Sona N. is reached; but dips steadily N.N.E. and N.E. at angles of 30° and 45°. There is then a certain amount of complication, by the introduction of the Siwalik conglomerate in a very thin broken bed; and by the flexuring which lets in the Nahans once more on the north side of the Sona N. This line of disturbance is a continuation of the line of thrusting or reversed faulting observed at the junction of the Peláni and Rámganga rivers.

As stated above, the general course of the Sona N. is through the sand-rock stage. For some distance up stream from the Rámganga the dip is 15° N.N.E. No other formation is seen in the actual river-bed until near Háthi-Khúnd; but on the slopes north of the river-bed the Siwalik conglomerate band, which has thinned near Boksár, is continued for a short distance and then becomes lost, to reappear again at Háthi-Khúnd. Thus, the horizontal section No. VII shews

no conglomerate, but the sand-rock is continued across the valley in a reversed fold, the axis of which follows beneath the line where the Siwalik conglomerate must once have been. In explaining the first reversed fault in the Rámganga-Peláni section, this state of the rocks has been alluded to. The thickness of the sand-rock north of the axis is very nearly equal to that to the south. The beds likewise harden away from the axis, and there is only a small amount of faulting or thrusting along what is very nearly an uninjured sigma-flexure. The lower bend of this sigma-flexure embraces the strata between the Sona N. and the plains; the middle limb is made up of the inverted sand-rock and Nahan sandstone between the Sona N. and the Káli-harpál (Kalee Hurpal) ridge (39) to the north, only slightly torn along the junction of those two formations; whilst the upper limb is formed of the strata on the north-east slopes of that ridge. This state of things not only proves the former extension of the sand-rock over that ridge to the north, but it also indicates that the first thrust plane or reversed fault in the Rámganga originated in a sigma-flexure, and did not *ab initio* begin as a thrust plane.

Continuing up the Sona N. above Dhánsi Chaor, we find at Háthi-Khúnd itself the Siwalik conglomerate once more retained in a thin bed along the axis of the flexure, which has now become almost a normal (unsymmetrical) synclinal, with the fault reduced to a minimum, or perhaps even absent altogether for a short distance; for the dips in the Kánia sót (40) on the north side of the axis are all S.S.W. at high angles of 70° &c., none of them being inverted, and there is very little discrepancy in hardness between the uppermost Nahans and the lowermost beds of the sand-rock stage. This dipping S.S.W. of the sand-rock stage, followed by a younger series in normal order, is an exception to the rule as previously formulated (from the section up the Peláni R.), that there is never a regular ascending series from north to south in anything but the youngest beds. Its exceptional character is further shewn if we ascend to the head of the Timal sót (41), an affluent of the Sona N.; for we there find the strike of the Siwalik conglomerate carrying it directly up to the high scarp of Nahan sand-

stone, the Thakal gádh dánda (42), which appears as a sudden bulging towards the south-west of the normal ridge of Nahans. There is therefore a manifest dip-fault, or horizontal displacement here, running E.N.E., which is doubtless connected with the slight cross-fault in the Peláni R. at the point where the nummulitics appear. It is owing to this exceptional fault that we have the seldom-seen normal synclinal fold, involving an ascending series from north to south. The following seems to have been the chain of cause and effect:—A sigma-flexure with reversed faulting was in the process of forming all along the south edge of the middle band of Nahan rocks. In some places, as in the Rámganga, the thrusting southwards of the Nahans over younger beds has been more prominent than elsewhere. Differential thrusting of this kind might either cause a transverse rupture of the above nature; or the order of events might be reversed, and a transverse rupture bring about differential thrusting. In this case the rupture seems also to be partly due to the sharp wrench in the general strike of the rocks which becomes north and south as it nears the Kotri N. But, whichever event came first, the joint resulting position is that, whilst the Nahans on the west side of the rupture have been carried southwards a great distance, the same beds on the east side, being relieved, have simply collapsed into the form of a normal flexure. The strike of the beds, on each side of this horizontal displacement, bends round towards it in the proximity of the line of rupture. Thus, its aspect, viewed on the surface of the ground, is the same as that of a fold-fault viewed in section. The south-westward bulging of the Nahan band west of the horizontal displacement is obviously a return to the position seen in the Rámganga; the amount of the thrusting is about the same; lowermost Nahans appear to be superposed on the top of a thin band of Siwalik conglomerate; whilst all trace of the northern half of the normal synclinal or the middle limb of the sigma-flexure in the sand-rock has vanished.

On getting to the head of the Sona N., the sand-rock to the south of the line of disturbance is still in force, rising into undulating hillocks with their triangular wedges very distinctly seen. Away to-

wards the plains they gradually rise into higher ground as lower and harder beds set in; and, finally, the Nahan sandstone shews beneath them in a normal and conformable succession. Travelling along the road to Kolu chaor, in the Kotri dún, from the head of the Sona N., we keep entirely to the sand-rock, and the only trace of the horizontal displacement is to be found in the curving of the strike. At the head of the Sona N. the latter has become east and west instead of S.E. and N.W.; then, after crossing the low divide into the Kotri dún, we find a return of the strike to S.E. and N.W., which is retained for some way, until near the Kotri stream when the strike becomes due north and south, and then a little east of north. The S-shaped trace which the strike thus makes is obviously of an analogous nature to the S- or sigma-shaped bend of a sigma-flexure.

Kotri or Sanneh R. (37)

In a section up stream from the plains along this river, there are first Nahan sandstones, somewhat disturbed, near the timber depôt at Sanneh (Sanai). As we traverse the first north and south reach of the river, we cross a synclinal with axis east and west and dips of about 20° on either side, increasing on the north side to 40°. The next reach, N.W. and S.E., shews dips of 40° towards the east, that is, at right-angles to the previous dips. Again, at Mandawala parao, half a mile further up stream, we have an anticlinal with axis east and west. A quarter of a mile further, at Gosam parao, an E.S.E. dip of 60° sets in and steadily continues decreasing in steepness to 30° as the Nahan sandstone merges into the sand-rock at Sain parao.

Kotri dún.

The river-bed has been a gorge hitherto, except near the mouth, but it now begins gradually to open out among the softer sand-rock. Several alluvial flats appear, helping to give the low undulating country the fictitious appearance of a dún. Remarkably good sections are exposed the whole way up this portion of the river. After the sand-rock has set in, the dips increase by degrees until at the junction with the Lakrawála sót the angle is 60° and the direction E.S.E. as before. Between here and Kotri village it oscillates between 60° and 55° and then once more

increases to 70° and 80° where the Siwalik conglomerate, the continuation of the thin band of the Sona N., is met with. It is very thin here, a mere relic, and after turning over to 80° W.S.W., there is a small interval of unseen ground where it may be inverted, and then we have the reversed fault separating it from the Nahans, which rise in a steep scarp and display very markedly their characteristic basal brownish and purple shales. The river-bed is now a gorge again, cutting through the Nahan ridge. The dips are at first due east at 60°, but this gradually changes to E.N.E. and then to N.E. at angles of 60° and 50°. This ascending series across the middle band of Nahans insensibly merges into the sand-rock at the junction with the Dimkeh sót (43), at which place the dip is 55° N.N.E. So far then there is a great resemblance between this section and the Rámganga-Peláni section; and the rest of the way to the main boundary across the Chokamb dún is also very similar.

Chokamb dún.

The Chokamb dún, which we now enter, is essentially low country, but, like the Kotri dún, lacking the real characteristic of a true dún, namely, the Siwalik conglomerate. It is entirely carved out of the sand-rock series, a continuation and expansion of the second sand-rock band through which the Mandálti R. runs. The expansion is due to the twisting of the strike, whereby the southern boundary of the sand-rock is thrown more towards the plains, following in an indirect and imperfect way the southward bulging of the middle Nahan zone in the direction of the Thakal gádh dánda. The dip in the sand-rock of this zone is N.N.E. along the Dimki and Debineh sots, first at angles of 50° and 40°, which increases to 90° at Debineh parao (44). It is not clear whether there is an inversion, or not, towards the next Nahan zone. If there be one, it must be slight; for the great disparity between the two rocks at their junction shews that the junction is far from being normal and conformable. Up the Bhir gadi (45), where it joins the Dimki, the dips are 40° and 30° E.N.E.

Mandálti (Mundaltee) R.

The Mandálti R., which is parallel with the Sona N., and analogous to it in every respect, takes its rise near Chokamb in a low flat divide between its bed

and the Chokamb dún. There are no good exposures of the rock in this very shut-in and winding stream. Such as there are merely shew sand-rock the whole way, dipping at high angles (80° and 90°) N.E. or N.N.E. A forest fire-line leading from Chokamb up to the Deolbári dánda (46) shews a fairly contrasting junction between the sand-rock and the third Nahan zone, indicating the presence of a reversed fault; but reliable dips cannot be obtained. The Nahans on the ridge are dipping N.E. 40°. The southern boundary of the Mándalti sand-rock band is simply one of passage from the Nahans into the former. The structure here, therefore, is merely a continuation of what we have seen in the Peláni R. above Gutua gádh. The third Nahan zone to the north of this is also simply a continuation of the same zone in the Peláni R. above Halduwála; whilst there is no reason to doubt that the main boundary to the north of it is in any way different to the same divisional line in the Peláni R.

Westward extinction of these dúns and longitudinal valleys.

As we stand on the flat little chaor of Chokamb, where there is a forest bungalow, we look west towards the Kho R. and observe that the low country which forms the Sona N. and the Kotri dún on the one hand, and the Mandálti R. and the Chokamb dún on the other hand, gives way gradually, so that the east boundary of the Kho R. is a continuous transverse ridge running N.E. and S.W. This expresses the fact that the two sand-rock zones, which give rise to those longitudinal valleys and dúns, have come to an end. After describing the section up the Kho R., we will consider this extinction of the sand-rock zones in its physical bearings.

COUNTRY BETWEEN KOTDWAR AND THE MITAWÁLA (MITHI) SÓT.

Orographical features.

The Sub-Himalayan zone between these two places is of narrower width than we have yet seen it to be. Having left behind us the Siwalik conglomerate and the sand-rock, the former of which practically dies out at the Rámganga,

and the latter at the Kho, we find that the Nahan sandstone and shales, which alone are left constituting the Sub-Himalayan band, present no orographical features which are distinctive of themselves. There are no longer a set of longitudinal ridges rising one behind the other, with dúns, or even low country between them. The Nahan sandstone of this tract is merely cut into a set of transverse hill-spurs, which descend towards the plains from the higher mesozoic and Himalayan ranges of hills, lying further to the north. The main boundary, in fact, is merely marked at the surface by a set of low gaps in these transverse ridges. The Sub-Himalayan zone, therefore, may be said to be welded without break into the older zones above it, so that denudation has cut through the whole as if they were one uniform block of conformable strata. A simplicity of structure is thereby presented by these Nahans which will not delay us long.

As a rule, the strata dip uniformly to the north-east, or thereabout; and, though very reliable sections are wanting, we shall see that the probability is in favour of the view that the whole is an ascending series from the plains to the main boundary, or very nearly so.

Kho R. (Kotedwar Glen). (47)

Up this river, in the Sub-Himalayan zone, there are dips of from 35° to 60° N.E. and E.N.E. The lowest beds seen near Kotdwar, at the mouth of the glen, have a large proportion of purple shales among them of the usual nature of the visible base of the Nahan stage. There are also some few of the conglomerate bands peculiar to this stage. Throughout the rest of the way up to the main boundary there are sandstones with occasional shales of the ordinary Nahan type. The following peculiarity, however, is to be noted. About two miles from Kotdwar the sandstone loses most of its ordinary characteristics, and becomes as if about to pass into the softer sand-rock. Thus it is certain that, though the two sand-rock bands are not actually present in the Kho, having died out as mentioned in the last section, the reversed faults to the north of them are still continued with less intensity across the Kho section; for further to the north-east, up the Kho, the

sandstone suddenly hardens again and then ascends gradually to the main boundary.

Nature of the dying out of the M. Siwalik stage in this direction.

There are three possible explanations of the dying out of the sand-rock bands in this direction. We may suppose (1) that they were deposited continuously over the area we are now entering upon, which was then upheaved, and they were denuded away before the two thrust planes came into existence; (2) that they were deposited continuously and then thrust over and buried by the Nahans, each in the form of a detached trough core (*noyau synclinal détaché par étranglement*)[1]; (3) that they were not deposited over this part of the country at all, or, in other words, that the Nahans here were elevated before the M. Siwalik age. I think a combination of the first and third of these suppositions the correct interpretation. It would be difficult to account for their sudden cessation west of the Kotri and Chokamb dúns entirely by thinning out, because there is such a very great thickness of them seen along the section up the Kotri stream. On the other hand, it would be also difficult to account for them entirely by the first or second hypothesis, because the reversed faults manifestly cease a short distance west of the Kho, there being no trace whatever of them in the Rausan N. in that direction. We may conclude then, that partly by thinning out, due to elevation, and partly by reversed faulting, the two bands of M. Siwalik sand-rock have thus come to a rather sudden termination.

Rausan N.

The section up this stream shews that, though the Nahan zone is as wide here as in the Kho, there has been no piling up of the strata, no reduplication of them by reversed faulting. The angle of dip is consequently low in a gradually ascending series, from harder Nahan beds with purple shales at the south end of the stream, to softer Nahans at the main boundary. The latter are not sufficiently high in the stage to be called sand-rock.

[1] See "Les Dislocations de l'écorce terrestre" par Emm. de Margerie and Dr. Albert Heim, p. 60.

CHÁNDI HILLS AND COUNTRY WEST OF THE MITAWÁLA (MITHI) SÓT.

This is the most westerly area which I shall have to describe in this memoir. It is bounded on the west by the Ganges; and so brings us into conjunction with the work already done by Mr. Medlicott, and with that which Mr. R. D. Oldham is now engaged in mapping on the 4-inch scale. Mr. Oldham has previously given a sketch map of this part,[1] the result of a few rapid traverses; whilst some of Mr. Medlicott's investigations extended a short distance in this direction east of the Ganges.

Surface features.

The aspect of the country shews a return to that in the neighbourhood of the Chokamb and Kotri dúns. There is a widening of the Sub-Himalayan area, embracing a further extension towards the south, and an inbaying up the Ganges valley towards the north. This widening is dependent on the appearance once more of the two upper members of the Siwalik series. Unlike the way they gradually disappear near the Kho R., they set in suddenly in this locality by a north and south fault; and having done so they continue for great distances along the Dehra and Kyarda dúns, &c. The widening of this portion of the country is accompanied by a slackening of the angles of dip, by undulating normal folds of gentler aspect than we have seen anywhere west of Rámnagar, and by a sudden dropping of the level of the country. The orographical features also at once mark the country as different from that I have just described. The low ridges follow longitudinally the strike of the beds, and the water-courses between them, in the main, also follow in this direction. In other words, the country once more takes its surface aspect very much after the pattern of the folds into which it has been thrown by the disturbing forces of upheaval, anticlinals forming ridges and synclinals valleys, all of which are more or less openly disconnected with the ridges and ravines of the Nahan and Himalayan zones above (see section IX).

[1] See Rec., G. S. I., XVII, p. 161.

Ganges R.

The Ganges, which flows along the western boundary of this portion of the country, marks the beginning of the Dehra Dún (48). The country here described is indeed structurally the termination of that dún. The same formations are found on both sides of the river, but in the Chándi hills, and the part west of the Mitawála sót, they shew a little more disturbance as they near the north and south fault which divides them from the Nahans. The Ganges at this place possesses a very wide river-bed of glistening white pebbles, cut into many channels, the water of which is artificially turned along certain courses for the purpose of feeding the great Ganges canal, the head works of which are at Hardwar. Hardwar is a well-known sacred bathing-place of the Hindus, full of small brick and stucco temples with their bathing ghâts facing the sacred waters. At certain times of the year the place is thronged with multitudes from all the surrounding parts of India, who attend the great fairs and for the purpose of dipping in the stream. But besides this, the Ganges valley at this point is the focus to which all going to the still more sacred fanes of Badrináth and Kedarnáth must trend. During the warmer months of the year, the dusty roads are trodden by a continuous stream of pilgrims, chiefly old men and women; who with their scanty savings, and a stout staff in their hands, make their way laboriously up stream with wonderful patience, that they may reach those snowy slopes and glaciers 12,000 ft. above the sea, the birthplace of the Ganges, before they die.

The following sections will illustrate the geology of this area.

Sidwála sót. (49)

This stream emerges from the low Chándi Hills near Kángri. Ascending it from that village, we first strike sand-rock dipping 70° S.W. This high dip gradually drops to 40° in that direction, a mile further up stream. There is then a normal anticlinal with beds on the north side dipping 20° N. E. This continues for two miles, sometimes increasing in amount to 30° or 35°. The Siwalik conglomerate then comes in, so far as I could judge, by interbedding with the sand-rock. The pebbles are at first small and sparingly dotted about in a sandy or loamy matrix,

and with numerous pure sand and clay beds interstratified. By degrees the pebbly beds increase in thickness and number, and in the size of the contained pebbles, until the well-known Siwalik conglomerate of ordinary type prevails with a dip of 30° N.E. It rises into steep scarps of bare rock. These cliffs form the watershed for the various feeders of the Sidwála sót, the Diowála sót (50), and other minor streams which flow S.W., and S. On the north-east side of the irregular line of cliffs the Siwalik conglomerate continues with the same dip as before, the country lowering in the direction of the Ghá-zirám-ka-sót, (51) towards which the water is now shed.

Returning to the sand-rock, we find the same general structure obtaining in it in a northerly direction along the edge of the hills from Kángri towards Chándi Pahar and the Ganges; save that the strike becomes N.N.W.—S.S.E. The southern half of the normal anticlinal is almost entirely swept away by denudation, and we have merely an ascending series dipping E.N.E. at 30°. The southern edge of the Siwalik conglomerate similarly bends round with the strike, but not quite to such an extent.

In the other direction from Kángri, towards Ganan trig. station (52), we have the same features marked in the sand-rock stage; the axis of the normal fold running a little south of that peak. Towards Godahwáli trig. station (53), however, the flexure gradually dies out, and the dips radiate downwards under the alluvial deposits of the plains in that direction. Thus, following the cliffs along the Paili Rau, up stream, we have first a dip of 60° S.S.W., then 40° S. and S. by E., then 35° S. E., then 30° and 20° E., and then E.N.E. and N. E. as the Diowáli sót is entered. The southern edge of the main mass of the Siwalik conglomerate does not however keep to the same line of strike, but bends round from the position we saw it had in the Sidwála sót to an E.S.E.—W.N.W. direction, then to an E. and W. direction with the inclination to the north, until it strikes the Mitawála sót and the north and south fault as shewn on the map. An outlier of the Siwalik conglomerate has, however, been left north and north-east of the Diowáli sót, bounded by a fault on the north-east side. This out-

lying portion, therefore, continues the structure and strike of the country as exhibited in the Sidwála sót. The fault on the north-east of the outlier brings in the sand-rock again, which shows signs of considerable wrenching near Khaira Chowki (54); but which eventually settles down to a dip of 20° N. underneath the main mass of Siwalik conglomerate. An inspection of the map will make this clear.

It would seem that the line of fault along the Mitawála sót has caused this singular wrenching, whereby the outcrop of the main mass of the Siwalik conglomerate takes a crescent shape. The strike of the sand-rock near Ganan trig. station not having followed this bending, a break became inevitable to ease the strain, and by it the outlier of the Siwalik conglomerate was dropped into its present position.

The Chándi hills, or "silver hills" as their name implies, are doubtless so named from the glistening appearance of the mica in the sand-rock, which is in a very rapid state of decay. The material of the hills is weathering in places at an enormous rate, so that the surface of the slopes is constantly suffering small slips which carry the soil and forest with them. It is probably on this account that the forest here is so poor as to be not worth working. The cliffs opposite Paili Chowki have their faces scored with deep vertical rain-furrows, and streaked by innumerable depending tear drops (imitating stalactites) of sand, which have dried in the act of running down. The country shews a great area of naked cliff, so that the rocks are ready dissected for geological examination.

Mr. Medlicott has generally described the geology of the Chándi hills in his memoir; and he draws attention to the return evinced here to the normal condition of the Sub-Himalayan zone, with a normal or unsymmetrical fold on the south edge, the steep limb of which is south of the axis.

I have dwelt upon the aspect of conformability between the sand-rock stage and the Siwalik conglomerate, because such an impression has invariably followed on every examination I have made with regard to the relations of these two rock stages. It is but fair to add,

however, that Mr. R. D. Oldham considers that there is an unconformability in some pebbly sandstones not far from the Diowáli encamping ground (55).[1] I was unable to find the precise position of this unconformability, which may have become covered up since Mr. Oldham visited the place. Mr. Oldham also states that he has found similar unconformabilities in the Siwaliks south of the Dehra Dún. From some correspondence which passed between us, my colleague seems inclined to regard them as mere local unconformabilities. From the numerous excellent sections which I have seen through the whole of these series, I gladly acquiesce in this, inasmuch as any thorough unconformability would surely have been manifest among these naked well-exposed strata.

Gházirám-ka-sót. (51)

This sót is cut out entirely among the Siwalik conglomerate, which has a good many clay bands interbedded with it. The sót runs generally along the axis of a synclinal fold, which is the complement of the normal anticlinal at the south edge of the Chándi hills. The hill spurs of the conglomerates on the south side of this sót display the triangular wedge structure noticed previously in many places, *e.g.*, in the country south of the Sona N. This, as before, is owing to the moderate dip of between 20° and 30° down the hillside.

Mundhal N. (56)

In the stream next to the north, named the Mundhal on the four-inch maps, but unnamed on the one-inch maps, the dips are entirely S.W. or W.S.W. at very low angles of 5°, until near Mundhal village where they are underlaid by the nearly horizontal sand-rock, which appears as a shallow dome, and occupies the low ground to the east of that village. The boundary between the two rock-stages forms a semicircle, and the dip of the upper beds is outwards from this line of junction. Northwards from this dome a narrow outcrop of the sand-rock follows parallel with the north and south fault, which can be traced the whole way from the Mitawála sót to the Bheng R. (situated on the north edge of sheet II of the one-inch maps.) The disturbance along this line of

[1] Rec., G. S. I., XVII, p. 164.

fault appears to have turned the dip in its vicinity at right angles to itself.

Country north of the Mundhal R.

The country to the north of the Mundhal R. is composed of the Siwalik conglomerate up to, and beyond, the Dogadi sót; and the beds seem to be very nearly horizontal, or with a slight flexure along the line of the Súnt sót (57). In the upper part of the Dogadi sót the dip is 30° S. W. and W.S.W.: but it lowers to 3° and becomes nearly horizontal on the north bank of the stream. The lower reaches become much covered by Recent gravels in the direction of Gouri-ghát; so that it is difficult to say how the rocks lie exactly, though they are very probably in a more or less horizontal condition. The continuation of the sand-rock outcrop, which appears east of Mundhal village, is last exposed in a very small cliff in the Bheng N.; save for one other isolated exposure opposite Rhikikes (Rikheekhes) which has a high dip of 70° S. E. (not included in the map).

Kauria chaor (58), and the plateaux between the Bheng and Rhikikes, are very much covered by Recent gravels; so that we can say no more about the Siwalik series here, than that they take a great curve up the Ganges valley.

It will be seen from the map that the main boundary in the Bheng meets the north and south fault a little further north in covered ground, and, therefore, that the Nahan rocks also come to an end with the Bheng. Their position up to that point from the Láldháng N. is simply a continuation of the same normal ascending series that we saw present in the latter stream.

Fault in the Mitawála (Mithi) sót. (59)

As described by Mr. Oldham, the sharp line separating the Nahans from the younger Siwaliks is undoubtedly a fault. A remarkable feature of it, so far as the younger Siwaliks go, is that the latter, although their general strike is nearly at right-angles to that of the Nahans, often have, in the immediate vicinity of the fault, a sharp bending either down towards or away from the fault. If the map be examined it will be seen that the south-east edge of the Chándi Hills, which follows the

course of the Paili Rau and the Mitawála sót, shows an abrupt twisting of strike; so that, by one means or other, the dip comes to be chiefly towards the line of fault. In the Mitawála sót, about 1¼ miles up stream from the present Láldháng-Chila road and near the old one as marked on the map, the Siwalik conglomerate is striking north and south, and the bedding is vertical.

It needs but a glance to see that this Nahan-Siwalik boundary is of a different nature to that which we have seen in any of the areas described further east. In many points it resembles the fault running parallel to and west of the Kosi R. It is certainly, as in the latter case, a fault separating gently undulating anticlinals and synclinals from a set of strata which forms but one-half of a much larger and grander flexure in an older rock stage. Again, by the way the different strata of the U. and M. Siwaliks impinge against it on the west, we see that it is not essentially a fold fault, like the Nahan-Siwalik boundaries we have hitherto examined. Primarily, then, it seems to have been a lateral wrench of the strata, or horizontal displacement; but in later times it would seem to have been influenced by an east and west crushing, which has brought about the sharp inclinations of the younger beds along the line of fault.

The Ganges fault.

In joining up my observations on the banks of the Ganges with those made by Mr. Medlicott and Mr. Oldham, I must first say a word or two about the Ganges fault. The curving of the axis of the normal anticlinal, as exhibited in the Sidwála sót, to a more northerly direction as seen near Chándi Pahar, favours the belief that it represents the Bhimgoda anticlinal of Mr. Medlicott,[1] the axis-fault having died out as stated by him. The flat synclinal in the conglomerate of the Gházirám-ka-sót I would also correlate with the synclinal in the Motichúr Rau (60). The normal anticlinal at Raiwála, which as taken by me had an axis N.N.W.—S.S.E. (not N.W.—S.E. as taken by Mr. Medlicott) would fit in with the similar flexure on the east side of the river up the Súnt sot. The flexures, however, are not quite continuous on both sides

[1] Mem. G. S. I., III., p. 123.

of the river; those on the west side are all a little further to the north-east. This expresses the break along the Ganges fault. But it also shews that simple upheaval and depression on one or other side is incompetent to produce the shifting. Apparent lateral shifting of beds may be produced by a vertical upheaval or depression if the strata are inclined in one direction only; but a series of undulations of anticlinals and synclinals can only be laterally shifted by a horizontal displacement. I am led, therefore, to the conclusion that the Ganges fault, like most of the cross-faults that I have seen in the Sub-Himalaya, arises from a horizontal displacement (*décrochement horizontal*). The bending round of the strike towards the line of rupture is manifestly part of the same movement: the bending was the precursor of the breaking.

The opposite dips on each side of the Ganges at Hardwar are (owing to this bending) not entirely due to the fault, but also in part to deceptive appearances; denudation having carried away most of the south-west half of the normal anticlinal near Chándi Pahar, and left it intact at Hardwar. The Bhimgoda[1] fault must have been a relief in part to the more energetic horizontal moving of the strata west of the Ganges. It, therefore, lessened the ultimate horizontal shifting, by retarding the movement of the Bhimgoda anticlinal in a north-easterly direction.

Mr. Oldham mentions[2] that at Raiwála the conglomerates on the west side of the river are opposed by the sand-rock on the east side. I think this must be a mistake, as I found nothing but conglomerate on both sides, as the map will show, until Rhikikes is reached. I connect the exposure there with the exposure in the Bheng, and with the long outcrop of the same running to the head of the Mundhal R. parallel with the north and south fault.

The horizontal section No. IX will be found to illustrate the general structure of this portion of the country.

[1] See Mem. G. S. I., III, p. 123.
[2] Rec. G. S. I., XVII, p. 166.

COUNTRY BETWEEN THE KOTAH DÚN AND THE WESTERN FRONTIER OF NEPÁL.

General remarks.

We may now return to the point whence we started at the beginning of this chapter, namely, the Kotah dún; and travel in imagination over the remainder of the Sub-Himalayan country intervening between that point and the Sarda R. The latter marks the boundary between Kumaun and Nepál; and where it issues from the hills is as great and important a river as the Ganges at Hardwar. The river-basin forms a main artery for such commerce as the hills afford; it being thronged during the greater part of the colder months by Bhootia traders and other travellers to and from the higher hills. This part of E. Kumaun possesses no regular dúns, although the valley of the Nandhaur, a few miles above Aonla Khéra, approximates very closely to one. This is accounted for by the prevailing rock being Nahan sandstone; whilst the M. and U. Siwaliks only appear as a few closely approximating thin bands in the central and wider portion of this Sub-Himalayan tract.

Having described with some minuteness the several portions of the country taken up in the earlier part of this chapter, in order to gradually familiarise the reader with the type of Sub-Himalayan rock structure, it will be unnecessary now to so closely detail each river section. Much of the country being a monotonous repetition of Nahan sandstones, with no striking peculiarities and no prominent geological horizons, there will be nothing lost by this brief treatment. Those parts, however, near the head of the Nandhaur and the Sara N., where a very complicated arrangement of the strata ensues, will be given due attention in the sequel.

Geological structure south of Naini Tál.

We have already seen (p. 33) that the eastern edge of the Kotah dún rises abruptly into a high ridge of Nahan sandstone, with numerous transverse side ridges and spurs; and that the Siwalik conglomerate of the dún is disposed horizontally against the up-turned edges of those sandstones,

as against a cliff. The Nahan sandstone here is of great width, holding entire possession of the Sub-Himalayan zone, and it continues so as far as the Balia ravine (61) which descends from Naini Tál. The main boundary up to this point continues in a fairly straight line cutting the Naini Tál-Káladhúngi road at Bijaun village (62), the Nehál R. near Nehálpúr, and thence crossing a little S. of Balne Khán and following parallel to and a little north of the Naléna R. (63) to Jóle kót. It is lost to view eventually in the Balia N. by a covering of superficial gravels.

The disposition of the Nahans appears to be that of an inverted synclinal, the axis of which runs along the ridge south of the Nalena valley. Whether this synclinal is broken along the axis, or not, by a fault, there are no data to say. North and south of it the beds harden considerably, and apparently by degrees; whilst along the axis they are soft and typically the uppermost beds of the Nahan stage. There is thus an inversion of the Nahans immediately south of the main-boundary fault.

At the Balia ravine this arrangement is broken by a cross-fault, a lateral wrench of the strata, plainly indicated by the swerving round of the dip towards it in the neighbourhood of the Nalena bridge on the bridle road to Naini Tál from Ránibágh. The cross-fault follows a line very nearly coincident with the Balia ravine, as far as the suspension bridge at Ránibágh (64). The main boundary by this fault is thrown southwards on the east side of it, so that the continuation of the main boundary, instead of passing a little south of Bhim Tál (as it would if undisturbed by the cross-fault), takes a new departure near the suspension bridge and follows the course of the Góla R. for some miles up stream. This general statement with regard to the Nahans in this neighbourhood will be sufficiently intelligible if the map with the dips marked on it be studied in conjunction with it. It must be inferred, however, that the lateral wrench of the strata along the cross-fault has been supplemented along its southern extension near Ránibágh by an up and down movement, the upthrow being on the east side; for the main boundary along the east and west

reach of the Góla R. divides uppermost Nahans from an old volcanic and granitic set of rocks to the north of it: in other words, the inverted half of the synclinal in the Nahans is not preserved here. It will be remembered that near the head of the Kánia (40) and Timal (41) sóts a similar cross-fault was accompanied by a like disparity in the sequence of the beds on each side of it. We had the uninjured synclinal in the sand-rock and Siwalik conglomerate on the east side of the cross-fault (corresponding to the uninjured inverted synclinal west of the Balia fault), and the ordinary ascending series with reversed fault on the west side of the fault (corresponding to the similar arrangement on the east side of the Balia fault). The difficulty of assigning the right order of cause and effect in the production of this arrangement is as great in the present case as in the previous one.

Golá R.

This river rises among Himalayan rocks, and after a while traverses very nearly along the line of the main boundary fault, and finally at Ránibágh turns south, cutting a gorge for itself through the Nahans to the plains. Tracing its course up stream from Káthgodám we find the section through the Nahans to be a very striking one as far as Ránibágh, on account of the great masses of strata that it reveals; bed after bed of sandstone and purple shale or hardened nodular clays coming into view with very nearly vertical dips over this 1½ miles of its course. I have already (Chapter III) drawn attention to the very great thickness to which the Sub-Himalayan formations attain; the Nahan band in the Kotri stream being over 6,000 feet and the bottom not seen there as elsewhere in this region. To the mere traveller by the tonga road to Naini Tál, or to the fisherman working his way along by its pools, the Golá R. section is a perplexing and striking one from the vast amount of strata laid bare. Even the geologist may be excused for momentarily losing his head when he passes across strata of one rock stage attaining such profound thicknesses. He may mentally compare this section with the sections exposed on the south face of the Salt Range, where the whole Palæozoic and Mesozoic record, including silurian, carboniferous, triassic, jurassic and cretaceous rocks, at its greatest is but

5,000 feet; and question within himself whether there is not something wrong about these great thicknesses. The stern logic of facts, however, must compel him sooner or later to see in the strata exposed from Káthgodám to Ránibágh nothing but a gradually ascending series of Miocene or Pliocene ages, from nearly vertical beds much jointed and hardened, to softer beds near the top of the Nahan stage, dipping 65° N.N.W. near Amratpúr. Not only is there a strong individuality in the rock, a general likeness throughout the section to warrant this belief, but it may be mentioned that specimens of fossil leaves have been obtained from the Nahan sandstone of this river and from that of the Nandhaur R.[1] which from their form and venation are seen to be angiospermous exogens, differing in no important points from those constituting the foliage of many trees living at the present day.

Main boundary near Amratpúr.

Ascending from Ránibágh along the bed of the Góla R., a very interesting assemblage of rocks is observed in the neighbourhood of Amratpúr, and one which has been wrongly interpreted by General Strachey.[2] I have stated that, if the lateral wrench of the strata along the Balia N. had not taken place, the main boundary would have passed much further to the north of its present position near Amratpúr. It was this break of continuity in the line of the main boundary, together with the presence of trap and granite apparently detruded south where the break occurs, that must have led General Strachey to regard the igneous rocks as intruded among the Tertiary strata, and therefore as being of Post-or younger Tertiary age themselves. With the good maps available to-day, and the systematic geological surveying of the area continuously from one point to another, a different light was at once thrown on the subject, which is really of vital importance in connection with the geological history of the Himalaya. In the first place, it must be understood that these traps exposed along the road from Bhím Tál to Ránibágh are not intrusive dykes, but consolidated

[1] Many good specimens have been obtained by Mr. Dhoarty whilst excavating for the canal at Chorgalia.

[2] Quart. Journ. Geol. Soc., 1851, Vol. VII, p. 296.

beds of old basic lava-flows ; for they are not only regularly interstratified with slates and quartzites of sedimentary origin, but they are also frequently charged thickly with amygdules of chalcedony and other secondary minerals, which fill up what were vesicles in the rock at the time of its birth. These filled up vesicles proclaim at once that the rock was exposed at the surface in a molten condition, that it was a flow or lava sheet and not a dyke rock. Furthermore, these supposed intrusive traps have not baked, hardened, or metamorphosed the Nahans in any degree whatever. On the contrary, these sandstones at Amratpúr in the vicinity of the trap are rather soft and friable, and exhibit no sign of having been subjected to such volcanic heat as must have been developed at the time those vast beds of lava welled up from beneath the crust. Still further, the rock next to the Nahans at Amratpúr and Amia village is not trap mainly, but a good strong granite of normal character and white colour : that is to say, a deep-seated rock, which could not have been formed except at great depths under conditions of pressure and very elevated temperature, and in the presence of water or water vapour—conditions which must have left traces of still more intense metamorphism in the rocks among which it was intruded than that due to lava. Again, the quartzites and purple slates interbedded with the traps represent contemporary sediments that were forming at the time the lava was formed ; and the signs of age stamped on them, that is to say, the pyro-metamorphism and dynamo-metamorphism which have affected them, illustrate the *least* degree of metamorphism we should expect also in the Nahans, were the latter older than the traps.

It is clear, then, that the Nahans are a younger set of rocks, separated from an older set of bedded volcanic and plutonic rocks which happened to be exposed in this locality during the time when the main-boundary fault was in progress of formation. As such, they are as distinct from them as from any other Himalayan rocks elsewhere in contact with them at the main boundary.

There are many other points of interest in these Pre-Tertiary igneous rocks, as we trace them along the course of the Góla R. up

stream, sharply marked off from the Nahan sandstone by the fault; but such detail belongs to the history of the strictly Himalayan formations, and cannot be introduced here in a memoir devoted to the Sub-Himalaya only.

From a little east of Amratpúr the main boundary follows the actual river-bed to a little beyond Amia. All along this line the rocks on both sides are much crushed. It then crosses and re-crosses the river, and afterwards follows a line north-east of the village of Jamiráni; the distinction between the two sets of rocks being well marked at the surface. The line of the main boundary has now gradually become south-east and north-west, instead of east and west,—a direction which takes it once more along the south side of the Góla R. close by the village of Múrkúndia. At the last-mentioned place a complication is introduced by these uppermost Nahans becoming still softer until they merge into a thin band of the sand-rock stage striking in the direction of Patráni. The map will shew how this band runs, the composing beds dipping 60° N. E. Its northern edge does not abut against the main boundary itself, but against more Nahans of a very low horizon from which it is separated by a reversed fault. E. S. E. of Múrkúndia these Nahans may be seen to be of a very hard and dark type of sandstone, dipping 60° and 80° N. by E. The main boundary to the north of the latter has now diverged entirely from the Golá R. and crosses the Karai-ki-gádh obliquely, and then re-crosses it some 2½ miles higher up, from which point it slopes gradually up the hill-side to Shâli lake (65) and Lohakhám temple, taking a direction about E. S. E. There are now two bands of Nahans and an intermediate one of sand-rock, occupying the Sub-Himalayan area. The narrow band of M. Siwalik sand-rock at Patráni trends south-east into the Nandhaur R., a little east of Khonáni (66), and concomitantly the Nahan band to the north widens and shews several closely packed folds.

Nandhaur R.

The portion of the Nandhaur R. below Khonáni resembles in its general curve that of the Gola R. and of many of the rivers further west, *e. g.*, the Kosi,

Rámganga, Ganges, and Beas, inasmuch as it first follows the strike of the beds and then by a bend (in the opposite direction to the hands of a watch) gradually works across the strike of the beds as it escapes to the plains at Chorgalia. Beyond the very interesting discovery of fossil leaves in the Nahan sandstone of this locality, there is but little to remark with reference to the lower parts of this river. The normal Sub-Himalayan dip prevails of 60° N. E. or E. N. E., until beyond Khonáni, when we gradually strike the sand-rock band, a continuation of that at Patráni. As far as the Ásni gádh (67) this band is not very broad, and it passes down into the sandstone to the south of it with which it conforms in direction and amount of dip. To the north its relation to the northern Nahan band is first normal, dipping steeply 80°, &c., to the south, as exhibited in a few stream beds such as the Ásni and Aonla Khéra gádhs. The valley of the Nandhaur, therefore, near Aonla Khéra (68), in its very apparent widening, expresses this synclinal in the sand-rock; which is shortly to be supplemented further east by Siwalik conglomerate being enfolded in that synclinal, the latter at the same time gradually becoming inversed as to its northern limb. The river at this position keeps to the south of the conglomerate by a series of sharp twists in steep-walled gorges. Further up stream, E. of Gauniá Rau (69), it widens again, and the landscape is very beautiful and undulating; the inversed northern limb in the Siwalik conglomerate becomes lost, as also that of the sand-rock. We then have the Siwalik conglomerate dipping in normal order against, and separated by a reversed fault from, the Nahans; or, if there be a thin band of the sand-rock between the two, it is completely hidden in all the exposures in the side-streams. The regular descending series from the reversed fault at the Nahans, through Siwalik conglomerate and sand-rock down to Nahans again, is evidently the normal Sub-Himalayan structure, such as was observed characteristically in the Pátli dún. The Nandhaur valley, along this reach, very much resembles a dún; it becomes broad and flat, and the river winds about in serpentine curves among recent gravel banks covered with sissoo and khair. The high dip of 60° and 70° in the conglomerate is the

one bar to the formation of a regular dún. With regard to the northern Nahan band, it can be seen from the map to gradually lessen in width in the direction of Dúrgapipal; the main boundary running towards that point from Lohakhám by the upper stretch of the Gaunia Rau.

In an easterly direction from this dún-like part of the Nandhaur, as far as Pátli village, there comes a very interesting and complicated arrangement of the strata, which is illustrated in the sections X, XI, XII, XIII and XIV. For the present, therefore, we will leave the Nandhaur, in order to describe those sections.

Kalaunia N., and country north of the Sára N.

The first section is taken parallel with the Kalaunia N. It illustrates the general structure prevailing across the whole of the Sub-Himalayan zone. Travelling up the Kalaunia gorge every variety of the Nahan sandstone is perfectly familiar; we recognise the well-bedded and jointed sandstones of dark greenish, greyish, and brown colours, with their subsidiary hardened clay and purple shale bands, the latter being very prominently seen about 1½ miles north of Kalaunia gót; we recognise the hardened concretionary layers, and the conglomerates of sub-angular pebbles of shale and clay and sandstone; and, finally, the passage up into the sand-rock stage in the Sára N. is also the same as of old, save that it is perhaps a little more sudden. The dips are due north near Kalaunia gót and apparently inverted, there being an inferred lying anticlinal (*pli couché*) near this place. The northern limb of the fold dips normally north at first, afterwards becoming N. by W. and N. N. W., and the angles increasing from 35° to 60°.

A little south of Silna jála the river bends east and west, and is named the Sára N. At this point the sand-rock comes in, and we keep on due north up the Réla or Raiála gádh (70). Entering that stream from the south we have the sand-rock stage for some way as characteristically displayed in all its composing elements as were the Nahans in the Kalaunia N., except that the thickness of the sand-rock is somewhat less than we have elsewhere seen it. The soft sands

and loams, slightly coherent, the inter-bedded concretionary layers standing out in the cliff sections, as also the clay beds and fine conglomerates, are as typically shewn here as anywhere in the western area near the Ganges; so that there is no mistaking them for anything else. They dip steeply at from 55° to 50° N. N. W., and at Bhút Bhéra they change into the Siwalik conglomerate by a gradual inter-bedding. The Siwalik conglomerate, however, has but a short career. Its exposure is less than ¼ mile across in this stream, and its lie is that of an easy synclinal, with low flat dips at the position of the axis. To the north its beds steepen, and the sand-rock then follows in normal order dipping 50° S. S. E. The E. S. E. strike involved in this dip, and the E. N. E. strike of the beds on the south side of the synclinal axis, if produced, meet about ⅓ mile to the east; so that the Siwalik conglomerate in that direction comes to an end. A curious case of pebble distortion in the conglomerate exposed here has been recently described by me[1]. It is not a mere flattening out of the pebbles against one another, but a crushing of one set over another set; so that they have been first powdered *in situ* (but in such a way as not to destroy the general structure of the pebbles, be they granite, trap or quartzite) and then drawn out along one line, either into fine thread-like processes, or into puckered or undulating layers like the mineral layers of a foliated rock. The sand-rock to the north of the conglomerate, through a short space of less than ¼ mile, increases in dip to the vertical, and then becomes inverted. Typical Nahans of very low horizon then come in suddenly, the thinness of the sand-rock on this side of the synclinal and the absence of passage beds into the Nahans shewing only too plainly the presence of a reversed fault between the two. In the sand-rock near the reversed fault, there are not wanting signs that more than one line of thrusting is present, and it seems extremely probable that a great many of the reversed faults in this Sub-Himalayan region are but seldom a single clean-cut fracture, and are rather a number of closely packed tears, all parallel to one another.

[1] Rec. G. S. I. Vol. XXII, pp. 68.

Bág Khóla (71).

The Bág Khóla section only differs from the preceding one by having a slightly wider exposure of the Siwalik conglomerate, which is also inverted at its northern edge. Nothing could be prettier, however, than the clear view of the folded synclinal obtained in the clean-cut little cliffs; every step in the process of inversion of the northern limb of the synclinal being well portrayed.

Raula Kándlo and Dhárapáni gád (72).

The view of the rocks of this glen is very nearly coincident with that depicted in section XI. The valley opens into the Sára N. near Kichail, among beds of Siwalik conglomerate. There is a black carbonaceous layer, about one foot thick, among the latter, near the entrance to the stream. There is no sand-rock to the north, but the Siwalik conglomerate abuts directly against the Nahan band; the Nahan-Siwalik boundary having obliquely truncated the latter so that it is not visible in the section. The Nahan band to the north, save that it is more contorted than usual, preserves a general resemblance in its main folds to the same zone further east.

Sections south of Katauti.

In the sections to follow complexity and added interest set in. The reversed fault between the younger Siwaliks and the Nahans can be seen to be a nearly uniform straight east and west line from the Raiála stream to the Pátkhóli Rauli. The main-boundary fault, in like manner, keeps a uniform line nearly parallel with it as far as the Gangolia gád south of Katauti. Furthermore, if these lines be produced in a westerly direction into the Nandhaur, we shall find their representatives as described in the paragraph devoted to that river. The intervening country, however, shews no Nahan sandstone at the surface; everything is Siwalik conglomerate as far as, and even beyond, the main boundary. In brief, we have overlap of the Siwalik conglomerate upon the older beds.

In section XII this is first illustrated. The Siwalik conglomerate in the Sára N. forms the lower bend of a sigmaflexure, broken by a reversed fault to the north of it. The Siwalik conglomerate in the

Gangolia gád (73) is a portion of the upper limb of the same sigmaflexure, though in a certain sense only, inasmuch as the conglomerates there are of much higher horizon in the Siwalik stage than those in the Sára N., and inasmuch as there is no sand-rock below them. Thus the conglomerate of Gangolia gád unconformably overlies the Nahans with no intermediate sand-rock, which must have been denuded away along what was a rising line of disturbance during an early phase of the same sigmaflexural movements ; which movements continuing later, when the conglomerates of Gangolia gád were deposited, finally influenced them also.

Herein it may be remarked that the section is very similar to that south of the Dhangari (19) and Sanguri (20) sóts ; and I would apply to both the same explanation regarding the absence of the lowermost Siwalik conglomerate, and of the sand-rock below the conglomerate, on the uplift side of the fault. That explanation demands that the line of the reversed fault be mentally represented, not as a sudden break, but as a continuous line of weakness from early in the M. Siwalik age up to late U. Siwalik times. Thus the sand-rock, and the lower beds of the conglomerate, if thinly deposited north of the fault at intermittent times, must, owing to the constant rising of that part, have ever been suffering almost contemporaneous denudation ; whilst the beds to the south were preserved by being forced below the reach of denudation. The Gangolia gád conglomerate, therefore, and that of Jirinjála (section V), are remnants which are on their way to obliteration. Their temporary preservation, however, is a valuable index as to the style of earth-movements along the lines of these reversed faults.

But we have also another very important deduction to make from this same conglomerate. We see that it overlaps, not only the Nahans, but also the Himalayan traps to the north, and that it truncates the main boundary fault in a most absolute and uncompromising manner ; thus shewing that the latter was altogether anterior to the formation of those uppermost Siwalik conglomerates. Lastly, the reversed fault bounding the Gangolia gád conglomerates on the north must be the most recent of all these lines of weakness.

Just as in the Peláni R., therefore, we have by an independent mode of reasoning arrived at the same conclusion, namely, that the reversed faults bounding different zones of the Sub-Himalaya are successional and not contemporaneous, and that therefore we cannot ascribe the whole of the folds and faults therein exhibited to one great earth-paroxysm of Post-Siwalik age.

Section at the head of the Sára N.

Section XIII, further west, shews at the surface an apparently consecutive ascending series in the Siwalik conglomerate from the Sára N. to the Mawala panigád (74). That such is deceptive, however, and that the reversed fault (Nahan-Siwalik boundary) is really present, but hidden, is indicated very plainly by the change in the conglomerate near the top of the ridge. It becomes almost entirely made up of large boulders of Nahan sandstone, instead of the elsewhere prevalent quartzite pebbles. The main boundary is overlapped by the conglomerate in the same way as in the last section.

Section south of Durgapipal.

Finally, section XIV begins to shew a return to the ordinary position seen in the Nandhaur R. The Siwalik conglomerate on the uplift side of the Nahan-Siwalik fault still over-rides a portion of the Nahans, but it does not pass across the main boundary. In addition, there is preserved a thin band of the sand-rock to the north of the uplifted Siwalik conglomerate. The latter is very remarkable for the large amount of the torrent boulders of Nahan sandstone contained in it. A somewhat parallel change in the sand-rock is also to be noticed. It becomes slightly conglomeratic, with pebbles of quartzite in it, though it never can be mistaken for the Siwalik conglomerate even for a moment.

Country east of Raiála gád and Kalaunia N.

The main boundary from near the head of the Raiála gád crosses through a gap in the ridge north of Maitiabanj, and from that point gradually descends the hill-slopes to the north; after which it strikes the Ladhia R. 1½ miles W.S.W. of Uparkót. Thence it keeps ¼ mile south of Uparkót, joining the Ladhia R. again 1½ miles further east; after which it follows a line generally coincident with the Ladhia as far as the Nepál frontier.

Except for a narrow band of the sand-rock east of Patli village, and extending as far as the small ridge east of Baiála, there is nothing but Nahan sandstones to the south of the main boundary, the whole of the rest of the way to the Sárda R. The Nahan zone presents the same characteristics as the Nahan zone south of Naini Tal; that is to say, it is a great inverted synclinal, with probably lesser folds borne on it. Beds considerably low down in the stage are present at the main boundary, and also along the plain-ward edge of the hills; whilst softer upper beds of the stage prevail along the central line of the zone. It needs no special description, therefore, and the mapping will be sufficiently clear by itself.

CHAPTER V.

GENERAL CONSIDERATIONS.

Resumé of earlier chapters.

In the preceding chapters we have briefly considered the superficial aspects of the country; we have also made, as it were, a dissection of the rocks from a mineralogical and petrographical point of view; subsequently, separate portions of the country have been taken and described as minutely as seemed necessary, with regard to the present disposition of those rocks, the nature of the disturbances which have affected them since deposition, the folds into which they have been thrown, the faults which have supervened, the relations of each of the formations to one another and to the older zones of the Himalayan area, and, lastly, proximate causes have been assigned to account for these folds and dislocations.

It now remains to consider the rock stages of this region in a wider sense, both in time and space: it is necessary to connect my work with that of other geologists among rocks of the same age and position, and to take a general view of those larger questions in which these rocks are involved in the whole scheme of the Himalaya.

I must, however, here state that it is not my intention, even if it were in my power, to discuss the whole question of the formation,

upheaval and present features of the Himalaya in their entirety. This memoir is simply concerned with a limited portion of the Sub-Himalaya; therefore, only so far as those fringing ranges offer evidence in behalf of the great chain shall I trouble the reader at present.

I presume that every reader of this work has previously made himself acquainted with at least the second part of the Manual of the Geology of India. That being so, he will appreciate the difficulties which surround any generalizations about the earlier history of these remarkable mountains. He will see that without crowding these pages to an enormous extent, and thereby obliterating any clear perception that might be gained, it would be impossible to do justice to all that has been written by former observers. Mr. Medlicott alone has put forward so many possible and probable hypotheses, so many alternative solutions, all of which are of the greatest use to the subsequent investigator, but the greatest torment to the scientific reader who merely seeks for a clear and coherent *view*, that it would be difficult to discuss the subject thoroughly without reviewing in all their different lights and bearings the issues that he has so well indicated.

In the remarks that follow, therefore, I shall only point out those deductions concerning the Himalayan range which must certainly follow from the study of the Sub-Himalayan tract. If they coincide with Mr. Medlicott's and other observers' prognostications, well and good: if not, it must be left for a future work to reconcile, uphold, or dismiss them.

Unity of work with that of Mr. Medlicott.

From the description given in Chapter III, of the petrography, there can be no shadow of a doubt as to the general identity of the formations with those embraced in Mr. Medlicott's classification. The fact that I examined the Dehra dún previous to setting about the study of my own area, and the fact that our two working grounds adjoin at the banks of the Ganges, make it as certain that the formations of both agree respectively as that the individual parts of my own area agree with them-

selves. The different bands of rocks, besides having strongly marked characteristics whereby they may be recognised, actually pass from one to the other of our working grounds (a proof of their sameness the most complete possible). That being the case, it would be waste of words to say more in enlargement of this truth. Beyond this, there is really very little else to do in this connection. As already stated, this work aims at being an extension of Mr. Medlicott's, and, therefore, so long as our two classifications correspond, the chief business of correlation is at an end.

The advantages of larger maps have enabled me to mark, with a separate colour, the M. Siwalik sand-rock, following Mr. R. D. Oldham[1] in this; whereas Mr. Medlicott represented the U. and M. Siwaliks by one tint on the map accompanying his memoir.

Possible slight discrepancy.

There is only one minor point on which I think it at all likely that I may prove at variance with Mr. Medlicott, At page 132 of his memoir he canvasses the possibility of a fourth group or rock stage, of lower horizon than the Nahans, and of higher horizon than the Sabáthu. (*N.B.*—Sabáthu here includes the whole of the Sirmúrs, *i.e.*, Kasauli, Dagshai, and Sabáthu proper). I have never seen any reason in Garhwál and Kumaun for the creation of a fourth stage. On the other hand, I have taken as the basis of my classification that the lowest rocks exposed south of the main boundary be called Nahans. Of course, had a section shewed nummulitic-bearing rocks in normal succession beneath Nahans, this decision would have had to be modified and an arbitrary line drawn between the two; but, until fossils had proved such a succession, I thought it better to call the older rocks south of the main boundary Nahans, although the presence of purple shales in greater preponderance in the lowest beds seemed to indicate a petrological change into deposits something resembling the uppermost Sirmúrs. I cannot but think that somewhere along the plainward edge of the hills there will eventually be found a section embracing nummulitics and Nahans in one normal succession, just as

[1] See Rec., G. S. I., XXVII, p. 161.

I have here shewn Nahans and M. Siwaliks in a like succession. But until they are so found it is safer to call the lower beds Nahans. I think also that this classification best agrees with that which Mr. Medlicott has adopted over the larger part of his area.

Still, should there be a slight discrepancy between our two classifications, I think it will be in this respect. My Nahan beds may possibly be, as a whole, of slightly lower horizon than Mr. Medlicott's; that is to say, I may have included with the Nahans older beds than he has, and drawn the line between them and the sand-rock stage a little below his.

Source of material of Sub-Himalayan rocks.

If we refer to what has been written in the foregoing pages about the petrology of the Sub-Himalayan system, we shall see that the mineralogical composition of the strata suggests something about the area from which the material forming them was derived. The presence of so much mica, in well preserved plates; of magnetite; and of occasional fragments of felspar; not to mention the very granitic appearance of much of the rock; shews unmistakably that the area from which this detrital material was drawn was one of crystalline schists or granitic rocks. The freshness of the material also proves that it cannot have travelled far. Every presumption is in favour of the belief that it came from the higher Himalayan range. That being the case, we cannot suppose that range plunged beneath the sea, or below the general level of denudation at the time of the deposition of the greater part of the Sub-Himalayan series. Apart from their geographical distribution and their fossil contents, there is this indication afforded by their minerals that the schists and granites of the Himalayan range were exposed at that time, though there is no proof here that they were in their present greatly elevated position. That the same minerals might have been derived from some other land is of course a possible, though not a probable, hypothesis. But, besides the commoner minerals herein mentioned, General McMahon (Rec., G. S. I., Vol. XVI, p. 186) has described several accessory minerals whose presence still more convincingly points to the crystalline rocks of

the higher Himalaya as their ultimate source. In rocks of the Sirmúr series and the Siwalik series he has found schorl, garnet, triclinic felspar and microcline, besides quartz shewing polysynthetic structure and containing liquid cavities and microliths. He writes, "All the above are eminently characteristic of granitic rocks and could be matched over and over again in the granites and gneissose granites of the Himalayas." At the very outset then we are reminded of the high probability that a barrier of crystalline rocks existed in Tertiary times between the Sub-Himalayan deposits of this side and those in the Hundes.

Conditions under which they were deposited.

The structure and fossil contents of the beds indicate the geographical conditions which prevailed during the deposition of the Tertiaries, as plainly as their mineralogical composition indicates the nature of the rocks forming the land from which they were derived. The marine origin of the Sabáthu beds, and the fresh-water origin of the upper Tertiaries, have long been recognised as facts. Moreover, the gradual passage of the Sabáthu clays into the sandstones of the Dagshai and Kasauli stages has also been accepted as proving a gradual change from marine conditions to those of fresh-water. Elevation was clearly going on in the localities where these rock were laid down, so that seas became estuaries, and estuaries dry land, and finally the younger Tertiaries, namely, the Nahans and M. and U. Siwaliks were deposited under conditions much like those under which the present deposits at the foot of the hills are being accumulated. I need not, therefore, make any further remarks upon this head, seeing that the rocks of this epoch, in the district I am describing, agree in all their facies with those as described by Mr. Medlicott. It is only when the Himalayan area is left, and we pass on to the Salt Range, the Suleman Range and the hills of Sind, that we find marine strata of greater thickness, and encroaching somewhat higher into the Tertiary series—a fact which indicates that the wave of elevation took place from the east to the west, whereby the sea was driven in that direction, and estuarine and fluviatile conditions supervened.

"A well defined petrographical whole of some order."

Another general consideration that strikes us in looking over the petrological characteristics of the Tertiaries is that they present, as Mr. Medlicott has shewn, "a well defined petrographical whole of some order." There is no alternation of deposits, such as would indicate a fluctuating condition of the earth's crust, except on a small scale. The whole set of deposits is steadily evolving in one direction. As to how this evolution, depending as we have seen on a wave of elevation proceeding from east to west, took place, we shall enquire later; I am at present merely drawing attention to those conclusions which follow from a simple inspection of the material and fossil contents of the rocks.

Absence of metamorphism.

A marked feature, on which I would lay stress, is that throughout the whole of the Tertiary zone there is no metamorphism of the strata, beyond a mere hardening of the lowermost beds by age. There is not even the presence of trap in the lowest Tertiaries, such as has been shown to exist in the Sind area and probably in that of Ladák. In the Góla R. I have described granite and trap in close conjunction with the Nahans, but from their not influencing the latter and from other reasons we have seen that they must be regarded as pre-Tertiary. At Kotedwar, also, in the area treated of in this memoir, we have an example of the near approach of the main boundary to the intrusive gneissose granite of Kálogarhi (Kálandánda), which is only about five miles away; but as there is no more metamorphism of the Tertiaries, including the nummulitics, in this position than elsewhere, we must without doubt relegate that gneissose granite at least to a pre-Tertiary time. Thus the absence of metamorphism in the Tertiary rocks pre-disposes us to regard the whole of the intrusive granite of the Himalaya as at least as old as pre-Tertiary—a point which has been disputed by some authors.[1]

No evidence of glacial conditions.

Beyond the few inferences above, I do not think we can draw more from a purely petrological examination of the Tertiary strata. I see no evidence

[1] See McMahon, Rec., G.S.I., XVI., p. 192.

for glacial action in any of the strata east of the Dehra dún. The presence of well-rounded pebbles in a clay matrix does not seem to me, of itself, to be proof either of glacial or extraordinary diluvial conditions. It seems to me merely to point to that particular form of deposition which must always obtain in a country subject to periodical rainy and dry seasons, namely, that during the rains each belt of deposited material stretches a long distance out from the mouths of the streams, but, when the amount of water in the stream bed diminishes, the carrying power diminishes with it, and mud is therefore deposited among the interstices of the torrent boulders discharged during the rains. Sub-angular and scratched stones, in anything approaching to a till or boulder clay, are unknown; as also is that peculiar form of ice-refuse of the nature of the contorted drift of Norfolk.

General considerations depending on distribution, and method of disturbance of the strata.

In turning from the broader questions involved in a study of the petrology of the country to those connected with the horizontal extension of the rocks, and the nature and meaning of the folds and disturbance zones into which they are thrown, there is a great temptation to wander aside into the fields of speculation: the mind is eager to leave the Tertiary records behind and to run riot among those scarcely decipherable monuments of the higher Himalaya. It would be a very pleasant excursion for the writer, and one might plead innumerable excuses for doing so: is not the Himalayan chain one, and can we divorce the Tertiary zones from the rest of the Himalaya? Has not every throe, as new formations were cast up from their deposition ground, vibrated through the great central mass of those glistening schists, and rugged granites, which rear their pine-clad summits far and still further beyond until they seem to melt among the clouds? But though such a prospect is seductive enough, the still small voice of scientific caution whispers to one that, if such license be prematurely given to the mind, to play with the bubbles of speculation, there may be a day of reckoning in the future when the minuter history

of the older rocks is more thoroughly worked out. How many heart-rendings will there then be should our theories too hastily formed dissolve like a dream before the clear daylight of advancing knowledge. Yes, we had better keep to the task imposed, as closely as human nature will allow.

Structure imbriquée (écaileuse).

Attention has already been drawn, in the section up the Peláni R., to the disposition of the disturbance zones, to their great extension lengthwise in the form of bands, to the northerly dip of their composing formations, and to the reversed faults bounding them on their northern edges. They are disposed in what has been elsewhere called *structure imbriquée* (*écaileuse*);[1] but with this peculiarity; that the uppermost member of each step or zone is younger as we near the outer margin of the hills. Let us look at this structure a little more closely. We have seen that it is extremely probable that the reversed faults belonging to this *structure imbriquée* were not contemporaneous, but successional; and I think there are certain considerations which will enable us to date their succession with some approach to accuracy. If we cast our eye over the map accompanying this memoir, and the smaller scale map of part of Garhwál,[2] we cannot help being struck by the peculiar manner in which a long narrow zone carries, as its uppermost member, a still narrower outcrop of some one formation. For very great distances we may see on the map, running parallel with the reversed fault, a thin line of colour representing a single rock stage. I may first instance the nummulitic band, which with a total thickness of a few hundred feet extends for 30 or 40 miles thus without any very marked increase in the width of the zone. I may also mention the thin band of Siwalik conglomerate which continues from the Kotri dún to the Rámganga R. and many of the members of the Sub-Himalayan series and the still older mesozoic formations. Lastly, the Sub-Himalayan group taken in its entirety is also an example of the great extension of a narrow belt of strata following a reversed fault for immense distances.

[1] See "Les Dislocations de l'écorce terrestre" par Emm. de Margerie and Dr. Albert Heim.

[2] Rec., G. S. I., Vol. XX., p. 26.

This peculiarity surely has a meaning, and the question is, what is it? I think it means that the uppermost member of each zone has been preserved intact for such long distances, because the fold involving that zone, and the reversed fault to the north of it, were the companions of the upheaval of that zone from a condition of deposition; that is to say, the uppermost stratum had only just been deposited when it was folded, and faulted, and so wrapped up with the older zone to the north that it was preserved from sub-aërial denudation.

Interpretation of the above structure.

For let us imagine a contrary case: let us suppose that the nummulitic strata, at the points where they are now seen to lie in thin bands, were horizontal, or approximately so, and covered by an immense thickness of Nahans and U. and M. Siwaliks before the reversed folding and faulting took place. What would have happened in that case? There is no such thing as a state of quiescence in nature: either a rock is being added to by deposition or it is being denuded away by erosion. Consequently, from the moment the nummulitics with their horizontal burden of Nahan sandstone and U. and M. Siwaliks rose from the level of deposition, they would begin to be acted upon by rain and rivers. As they continued rising, they would become cut into and sculptured in every direction by valleys and gorges; so that a geological map, if then drawn, would present all those winding, circular, and ellipsoidal outcrops peculiar to a country of horizontal strata. The result of a lengthy interval between upheaval and folding would be an irregular patch-work of strata, with innumerable outliers of younger formations upon older. In some places the nummulitics would remain covered by a great thickness of newer strata, in others they would be worn away perhaps to nothing. Let us now suppose that a crushing sets in, a lateral pressure of the mountain mass acting since the deposition of the U. Siwaliks, and accompanied by reversed folds and fold-faults. Could we then have that irregular patch-work of strata falling into zones of formations of the regular kind I have described as actually existing? Could we then expect to see the long narrow outcrops of

the nummulitics and other strata continuing without alteration in thickness for a distance of thirty or forty miles? I think not; the outcrops of different beds would constantly impinge against the fault, so that the fault would now lie to the north of one formation, and now of another, whilst it would never continue for any distance inseparably connected with a single formation.

Thus, coming back to the state of things as they are in the region before us, I see no escape from the conclusion that the unvarying thickness of the *outcrop* of the uppermost member of a disturbance zone is the direct projection on the surface of the earth of a *deposit* of unvarying thickness from one end to the other of the exposure; that is to say, of a deposit that has never suffered denudation to any extent before the folding process began. But it is clear that, if the strata were not elevated above the line of deposition, they must have been depressed beneath it, and therefore in the act of forming, up to the moment of their upheaval and crushing.

The concrete result of this somewhat cumbrous argument is that we can supplement the inference that the five reversed faults in the Peláni R. were not contemporaneous, but successional, by the additional inference that the date of the production of each must have been a little later than that of the formation which lies to the south of each. Therefore, the southermost reversed fault in the Rámganga-Peláni section was produced, or at least completed, about the conclusion of the U. Siwalik stage; the next reversed fault about the conclusion of the M. Siwalik stage; the third reversed fault about the conclusion of the Nahan stage; the fourth about the conclusion of the nummulitic stage; and the fifth doubtfully at some period between the massive limestone and nummulitic stage

Each reversed fault represents an ancient shore line, or mountain-foot; *i.e.*, a limit of deposition.

Another important point in connection with this subject is that in nearly every case I believe the fold-fault to have taken place approximately near to the original shore-line or mountain-foot, as the case may be; so that these reversed faults are at the

same time in a certain measure limits of deposition for the formation immediately south of each.

Northern limit of the Siwalik conglomerate.

Mr. Medlicott very early came to the conclusion that the nummulitic boundary, the main boundary, and the Nahan-Siwalik boundary were practically limits of deposition; and his reasons are so clear and decisive as to be convincing. Taking the youngest member of the Tertiary zone first, namely, the Siwalik conglomerate, no man having once looked at its geographical position would for a moment entertain the idea that it had ever extended in an unbroken sheet far away into the region of the Outer Himalaya. As early as the first quarter of this century Dr. Hugh Falconer, whilst collecting the vertebrate remains from the Sub-Himalayan hills, remarked on the similarity between the Siwalik conglomerate and the present deposits of the large rivers. He says [1], "If the beds of the Jumna and Ganges were to be upheaved in the "same way as those of former rivers, the appearance of the strata "would be exactly similar." Mr. Medlicott, carrying out the same idea, found in the course of mapping the area north-west of the Ganges that the Siwalik deposits varied according to their position with regard to the great rivers. He remarks [2] "in the range between "the Ganges and Jumna clays are very subordinate, and the conglo- "merates are composed of the harder quartzite pebbles, just like the "shingle now found in the great mountain torrents. This portion of "the range is in fact an ancient diluvial fan of the rivers Tons, Jumna, "and Ganges." A similar generalization holds in the country taken up by the present memoir. Between the Ganges and Rámganga, a short distance from the plains, there rises an elevated schistose area, crowned by a mass of gneissose granite forming the summit of Kálogárhi (Kálandánda), and without any important rivers draining south. Now, it is here that there is a corresponding absence of the U. Siwalik zone. The eastern termination of the Chándi hills represents the eastern limit of the deposits of the direct parent of the Ganges and

[1] Palæontological Memoirs, Vol. 1, p. 33.
[2] Manual of Geol. of India, p. 541.

for a long distance both U. and M. Siwaliks are absent. Beyond the Kho M. Siwaliks set in. As we near the Rámganga the narrow band of Siwalik conglomerate running from the Kotri stream to the former river indicates the very opposite of energetic torrent and river action in accumulating thick beds of coarse detrital material. On the other hand, at the debouchure of the Rámganga and the Kosi, we have once more a great thickening of the conglomerate; the wandering of the Rámganga to the west along the Pátli dún leaves in its train all that thick low range of conglomerate to the south as an indelible mark of its former activity. Again, the Kotah dún conglomerates are so palpably an ancient river fan spreading out from the present Kosi river-bed that they need no remark. Their eastern boundary at Káladhángi in a similar manner marks the limit of the Kosi's former activity in that direction: for there are no more conglomerates at the foot of the high Naïni Tál hills where large rivers are absent.

Nothing is more clearly demonstrated in the whole range of Sub-Himalayan geology than the connection between the position of the debouchure of the present large rivers and the deposits of Siwalik conglomerate. That being so, we are bound to believe that these deposits were formed by the direct parents of those rivers, in the places where they are now found; and it would be as impossible to credit the belief that the conglomerates could once have extended far into the hills as it would be to find the Bhábar deposits in a similar locality.

Apart from these considerations, I have shown that the northern boundary of the conglomerate becomes undoubtedly an approximate limit of deposition in the section south of the Sanguri sót, and actually a real limit on the north side of the Kotah dún. Thus, the configuration of the southern margin of the Himalaya must have been very much what it is now in Upper Siwalik times. The absence of outliers to the north of the boundary is negative evidence favouring the same conclusion; but too obvious to be more than mentioned.

If we now take the fault separating the sand-rock from the

Nahans, we find that what is true as regards the original limitation of the Siwalik conglomerate is true also of that of the sand-rock, though in a less degree. The rivers then were not so exactly placed as they are now, but still their general disposition must have been very much the same.

The main boundary also a limit of deposition.

The main boundary between the Nahans and the older rocks to the north must also be looked upon, though still less absolutely, as a limit of deposition. The winding nature of this fault, as it follows the main curves of the Himalayan range, is the chief argument that we have to rely on here. In the case of many of the larger rivers we see an inbaying of the boundary towards the hills, corresponding to what would be a present contour line. Take a look at the geological map accompanying Mr. Medlicott's memoir, and see how at the north-west end of the region there is a sharp inbaying up the Ravi; then a steady line following the trend of the Dhaoladhar ridge; then a great inbaying, on a large scale, towards the debouchure of the Beas R. from the higher hills; and then a more or less steady line until the Jumna is neared, when another inbaying of the boundary takes place, followed by smaller bends between that point and the Ganges. That the same is true in the region covered by my own memoir is similarly apparent to the eye. Can a boundary such as this be anything but an approximate boundary of deposition? Can we for a moment suppose the Nahan zone a fragmentary relic of a great fold of the rocks which carried them once far above the Outer Himalayan mountain mass? Decidedly not; this moulding of the Nahans in and out among the irregularities of the older mountain mass is the natural result of deposition round a winding mountain-foot. The Himalaya must have stood roughly blocked out as they now stand when the Nahan sandstones were being deposited. We have already seen that the minerals of the sandstones tell the same tale; whilst the embedded mammalian remains point also to a limited deposit, with high land not very distant, from which the material was derived in which their remains were speedily and

regularly engulphed. Then, as now, there was a sub-tropical Bhábar zone at the foot of the Himalaya, where a mightier race of giant proboscidians, and other extinct vertebrates, trod the earth by the banks of rivers not so very unlike the Rámganga, the Ganges, the Beas and the Ravi of to-day, and which had their source in a range of central peaks of an outline much resembling those which now prevail.

Limits of the nummulitic zone.

With the nummulitic zone our proofs of a northern limit are rather weaker, and cannot be too much insisted upon here; but, considering the estuarine conditions under which they must have been formed, their rapid horizontal change in a northerly direction, as mentioned by Mr. Medlicott, near Sabáthu, and their tenacious restriction to heights of about 3,000 feet on the plainward face of the Himalaya, I think we are justified in denying that they ever existed over those higher tracts of the outer and central Himalaya, where never an outlier of them has been detected. That this general conclusion is not affected by their presence at 12,000 and 15,000 feet near the source of the Indus, and by the probability that there was a depression in nummulitic times running through Kashmir, connecting those deposits with the nummulitics of Hazára on this side of the main range, I shall shew later on. For the present I think there is sufficient evidence to prove that many, if not all, of the reversed fold-faults, which cut off each of the Sub-Himalayan zones to the north, are approximately coincident with limits of deposition; and that, therefore, they took place either along a shore-line or mountain-foot.

Physical aspect of the present mountain-foot.

And this argument is strengthened greatly by the behaviour of the present mountain-foot towards the deposits of the plains. There are not wanting signs that the southern margin of the hills has become, or is tending to become, a reversed fault. These are some of the signs. Nowhere along the whole length of the Sub-Himalayan zone can we point out a low, steady dip of the Siwalik conglomerate towards the plains; although it is absolutely certain that such a dip must have obtained on the first elevation of those strata. What has become of that southerly dip?

I think the question is best answered by reference to the south edge of the Kotah dún, where we have the Siwalik conglomerate very little disturbed as a whole, and therefore more likely to shew the preliminary stages in the development of any marginal fault that may occur. We see there at the south edge of the hills a rapid bending over of the beds towards the vertical, with even inversion as in the Ladwa gádh. That accelerated dip in the more disturbed areas of the Siwalik rocks further west has vanished, and the problem is, how? Taking a definite portion of the country south of the Pátli dún (see section V), what has become of the southern half of the normal (unsymmetrical) anticlinal in the sand-rock and Siwalik conglomerate, which we may assume by analogy was once present? There is no reason to suppose it denuded away entirely any more than the northern half; but there is strong reason for believing that, if we accentuate the earth movements which in the gently undulating area of the Kotah dún were nevertheless able to produce so sharp a bending to the south with slight inversion, we shall arrive, in the more crushed area of the Pátli dún, to a state of complete inversion and production of a fold-fault. The normal fold with its sharp "*dejettement*" to the south must result in an inversed fold, or sigma-flexure, when further crushing has supervened; and the latter will inevitably carry with it a fold-fault of the nature of those about which I have already written sufficiently.

I see no escape therefore from the general conclusion that, wherever the southern margin of the Siwaliks shews no relic of a "*dejettement*" to the south, it is because a fold-fault has supervened along what is now a limit of deposition for the Bhábar zone of gravels, sands and clays.

Contrast of the south face of the Himalaya with the eastern aspect of England.

How different is the structure of this fringing zone of Sub-Himalayan rocks from that of the eastern counties of England! As we travel inland from the shores of the North Sea, we ascend over strata successively older; our feet tread first the Tertiary or the post-Pliocene boulder clays, then the cretaceous chalk formation, then the Neocomian, then the oolites, and so on; whilst every one of these strata dips,

as a rule, beneath those of younger age, that is to say, towards the present region of deposition. Here on the margin of the Himalaya we have the *structure imbriquée ;* we ascend from the plains over blocks of strata all dipping away from the present region of deposition, and, though each step or disturbance zone is older as a whole, the individual members are arranged in the opposite manner to what they are in England. There is no parallelism, there is no compromise, between the two countries; and the deduction that sober reasoners will draw from this is that either the nature, or the amount, of their disturbance must be very different.

Some other points of general importance may now be noticed.

Nature of the unconformability between the Siwalik conglomerate and the Nahans, south of Sanguri sot.

In describing the country to the south of the Sanguri sot I mentioned the occurrence of uppermost Siwalik conglomerates in most palpable unconformability on the up-turned edges of lowermost Nahans. A similar relation is also seen on the north and east sides of the Kotah dún and north of the Sára N. In other parts of the country, for instance, in the Rámganga-Peláni section, I pointed out a normal ascending series of strata without break from the base of the Nahans up to the top of the Siwalik conglomerate.

From the very many excellent river sections that I have observed I cannot persuade myself that this ascending series is anything but regular and conformable, and I think it unnecessary to assume, as Mr. Medlicott has done on similar grounds,[1] that the state must be one of apparent conformability only, with an undetected line of division between the two. As already stated by me, the immense thickness of the Sub-Himalayan deposits from the Nahans upwards, which average 16,500 feet in the area covered by this memoir, as well as other considerations, imply a long epoch of time; so that there is no anomaly in imagining their continuous deposition along one line, and a gradual and simultaneous crushing up of them along another adjacent line. Indeed, the evidence of the progressive and successional folding and faulting that have taken place throughout the Sub-Himalayan zone leads

[1] Mem. III, G. S. I., p. 104.

me very strongly to accept the view that the southern edge of the hills at the present day is a limit of disturbance in that direction, and that it was so during the ages when all the different stages of the Sub-Himalayan series were deposited. Thus I conclude that quiet and uninterrupted deposition was ever going on south of the southern border of the elevated land or mountain area, and that progressive slow and regular crushing was taking place north of that border. It can readily be seen that, by these processes, the apparent anomaly of great unconformability between the uppermost and lowermost beds of the series at one point, and of regular conformable sequence through that series at another, is accounted for—the great interval of time required for the deposition of the conformable series being represented by the gap in time implied by the unconformability.

The same reasoning would lead one to suppose that though the Recent gravels and alluvium of the river terraces are seen in many places to lie unconformably upon the edges of Siwalik strata, they may, nevertheless, be conformable to, and pass down into, the latter a little distance away to the south of the edge of the hills. The conditions for bringing about this state of things, when brought to their lowest terms, are simply a sinking or under-thrusting of the plains at the foot of the hills and a rising or over-thrusting of the hills themselves.

The disturbance of the Sub-Himalayan rocks not representative of that of the older rocks.

Another and a very burning question is, how far the disturbances evinced by the Sub-Himalayan zone are represented in the older Himalayan rocks. It is constantly assumed by many geologists in England that the immense contortions and inversions of the Sub-Himalayan formations express, in themselves, all the machinery of upheaval and contortion of the great Himalayan chain itself. This is a point I cannot concede. Even if, as is often assumed, the Himalayan and Sub-Himalayan sets of rocks shewed a perfect parallelism in their lines of disturbance, I should still be unable to subscribe to it. But, in the first place, such a parallelism does not exist *everywhere.* Over a great part of Kumaun there is a direction of strike running north and south. It begins in a set of basic volcanic and

micro-granulitic rocks which are folded, crushed, and cleaved by a pressure which has acted in an east and west direction. These rocks run from Bhuwáli near Naini Tál to Khairna, and the same line of strike is continued east of Ganai along another set of volcanic rocks up to and beyond Lobah, near which place, as I have described in the "Records," they are separated from the schistose area of Dúdatoli by a great fault running also north and south for a great distance, until near Chándpur Garhi where it turns away to the west. These two sets of rocks disturbed by east and west crushings are interfered with across the middle of their course by the schistose series at Ránikhet and Dwaraháth; but I think they are, nevertheless, connected. That line of north and south strike extends for about 60 miles, and makes an angle of 60° with the neighbouring strike of the Dúdatóli schists, &c.

Neither can it be considered to be due to a mere accidental variation of dip. The intensely crushed condition of the traps and micro-granulitic rocks about Khairna is of exactly the same order as that which I have described in the traps north of the Dúdatóli area. The crushing is one which has taken place in the cold and solid state of the rock. It has affected not only the finer crystalline portions of it, but also the amygdules present in the vesicles of the rock, which have become drawn out into shreds. It has cleaved the rock; and where larger crystals occur in the micro-granulite they have become eye-shaped by the same means. In some cases the rock is absolutely powdered up into dust.

More than this, this set of rocks at Bhuwáli is continued south nearly to the Góla R., interbedded with a few quartzites and slates. The strike of cleavage and bedding is, as before, north and south very nearly. Close by the Góla R. they come to an end suddenly by the Nahan sandstone, which is striking in an exactly opposite direction, and dipping towards the north at 65°.

The lines of disturbance, therefore, in *some* Himalayan rocks do not coincide with those of the Sub-Himalaya, nor with other Himalayan rocks, and must have been due to other and older directions of thrust.

But, besides the *direction* of disturbance not always being the same, the *amount* of it is very dissimilar in the two rock groups. The older rocks exhibit a very much more intense and prolonged crushing than the younger Tertiary rocks. This is represented by the dynamic metamorphism to which the former have been subjected. Examples of plutonic, volcanic, and sedimentary rocks which have all undergone intense crushing, with production of either cleavage, augen or lenticular-tabular structure in them, have been given by me in the Records.[1] Ordinary granite is very seldom to be met with: it has nearly always been converted into gneissose-granite, the individual felspars having been crushed into one another until the rock assumed a lenticular banded appearance. Some basic plutonic rocks have suffered in the same way. It is also difficult in many places to find a normal unaltered trap; and the rock is sometimes so much altered as to be scarcely recognisable. Quartzites, containing pebbles, have also been described as converted into quartz-schists; the different grains of quartz having been broken and run together into lenticular bands, like the crystals of felspar in the gneissose granite, and films of mica developed between them. All these peculiarities bespeak age and intense dynamic metamorphism. And there are no like evidences among the Sub-Himalayan rocks. The latter have been crushed and contorted as to their strata; they have been wrapped into immense sigma-flexures, and cut up by reversed faults; but of cleavage and dynamic metamorphism they show no sign.

In his memoir, Mr. Medlicott declared his belief in the distinctness of the disturbance which upheaved the main Himalayan chain, and the disturbance which in later times affected the Sub-Himalaya. He wrote[2] "These remarks lead me to the conclusion that the features of disturbance in these youngest rocks have no direct connection with *the formation of the mountains*. But connection there most decidedly is. I believe the disturbance of these rocks to be entirely a *reflex* effect. As the composition of the Siwalik strata and their enormous accumulation give evidence of the vast denuda-

[1] Rec., G. S. I., XXI., p. 11. [2] P. 169.

"tion to which the older Himalayan rocks have been subjected, so the "disturbance of these strata gives more positive evidence of a period "of *decadence* of the Himalaya. I can see no explanation of these "contortions but in the thrust from the mountain mass consequent on "the sinking of that mass." This was Mr. Medlicott's belief when he wrote the memoir. His later remarks in the manual are more uncertain, and he appears to leave it an open question whether the Himalaya were first contorted and upheaved in pre-Tertiary times, and then upheaved again; or upheaved first in the form of a "*bossellement*" or warp, and contorted only during the later Tertiary ages.

It will be seen from what I have written above that I so far agree with his former statement in the memoir as to believe in the distinctness of the disturbances affecting the Himalaya and Sub-Himalaya, respectively, in the part of the country examined by me; but I look upon it as one of degree and not of kind. Instead of the Himalaya sinking, I think they are still growing; and that the upheaval of the several bands of tertiary rocks is simply the result of a continuance in later times of the same earth movements that have for many ages before been upheaving the older formations of the Himalaya.

Other Hymalayan problems.

That there are many difficult problems concerning these mountains not yet satisfactorily disposed of, no one will deny. The word "Himalaya" is extensive in its application, and covers such vast regions that a uniform scheme of upheaval and contortion can only very doubtfully be applied to every part of it. There are one or two points that always have, and always will have, the greatest prominence in the consideration of any such scheme. These points are (1) the undisturbed position of Siwalik strata at 12,000 feet in the Húndes; (2) the presence of nummulitics in a rather more elevated position near the head-waters of the Indus, highly disturbed, and resting unconformably upon disturbed gneiss;[1] (3) the great sequence of unaltered sedimentary

[1] Mr. T. D. La Touche, Deputy Superintendent, Geological Survey of India, has recently described (Rec., G. S. I., Vol. XXI, p. 160) nummulitic bearing strata in Zánskar at an elevation of 18,500 feet, the greatest altitude at which these strata have hitherto been obtained *in situ*.

formations, ranging from Silurian to cretaceous, described by Stoliczka, and occupying heights up to 20,000 feet, in a very little disturbed basin to the north of the main gneissic axis of the Himalaya. These points have been discussed by Mr. Medlicott in the manual. Until Captain Griesbach's memoir on those and neighbouring regions is published, or until some other investigator brings forward more positive physical details concerning their arrangement than are at present forthcoming, it would be inopportune to discuss the subject again.

There is only one consideration that I would like to lay stress upon, namely, that if in any one or other locality, though all are embraced in the general name "Himalaya," there are found to be physical interpretations of the structure of the mountains differing essentially from those which have been attempted in this memoir, or from those of any other part, I would ask that not therefore on that account should one interpretation be held as disqualifying another; but that all be taken as applicable, each in the individual area with which it is concerned, until all the different localities have been so dovetailed together by further research that a fair and reasonable generalization can be undertaken, it may be on wider, more liberal, and more intricate principles than have yet been conceived.

CHAPTER VI.

GENERAL CONSIDERATIONS—*continued.*

Abstract theories of mountain-making.

Every worker in mountainous regions, besides keeping his eye on the ground beneath his feet, and keeping in mind the problems connected therewith, is naturally impelled to see in the inferences that he draws a justification of some, and a refutation of other, cosmical theories with regard to mountain ranges in the abstract; and especially is this the case when the geological structure he is engaged upon has been adduced by any writer in support of any one abstract theory of mountain formation. I therefore feel it a duty to say a word or two in this

connection, for every writer who puts forward a world-wide hypothesis of this kind should, and no doubt does, expect it to be confirmed or refuted by different labourers in their own fields.

The subject is of course a little discursive, and must lead one to consider principles as well as facts, and to touch on evidence derived from other countries. Let us then turn to a recent book, "The Origin of Mountain Ranges," by Mr. T. Mellard Reade, and see whether the structure of the Sub-Himalaya as interpreted in the foregoing pages of this memoir is in agreement or otherwise with that author's conclusions.

Considerations of Mr. Mellard Reade's theory.

Fortunately for the critic who has not unlimited space at his disposal the fundamental doctrine of "The Origin of Mountain Ranges" is easy to comprehend and tersely expressed; though unfortunately the argument is also terse, whilst the bulk of the book is taken up with descriptions and illustrations from many of the mountainous regions of the earth, which seem to me to be only sometimes relevant to the theories propounded, and with laboratory experiments, which I think are too artificial to be taken seriously as working models of the crust of the earth. With reference to the latter it is manifestly impossible to produce with the means at our disposal the condition of rocks at great depths and under the enormous pressure to which they must be subjected. Matter there must be in a state of which we have no experience, and attempts at imitation can at the best be but caricatures.

The key-note of Mr. Mellard Reade's book is that mountainous regions have been areas of great sedimentation, both vertical and horizontal—a sedimentation which is supposed to have raised the isogeotherms among the mass of those sedimentaries, thereby producing expansion by the increased heat. Thus it comes to pass that great sedimentation is the forerunner of upheaval, and also a factor in the *cause of it*. It must be noted here that the author gives no proof that sedimentation raises the isogeotherms, but merely states that "in 1834 Babbage . . . . pointed out that the addition of

"sediment to any part of the earth's crust must raise the temperature of "the portion of the crust it covers"[1]; and later, that Captain Dutton, of New Zealand, accounted for the anticlinal of the Weald through the rise of the isogeotherms caused by sedimentation.[2] Now, it is easy to see that, if a trough-like sea, of a certain depth, becomes gradually shallower and shallower as sediment is poured into it, there will be a rise in temperature of what was once the bottom of that sea; but all cases of great sedimentation cannot be considered in this simple form. No one will suppose that the accumulation of 20,000 or 30,000 feet of strata took place in a sea which was once of that depth and which gradually became silted up. Great sedimentation of this kind can only take place by concomitant sinking of the sea bottom; so that the rise of the isogeotherms being interpreted means merely the sinking of the floor on which the deposits were laid down. At page 266 the author recognises this when he says "the accumulation "of a great thickness and extent of sedimentary deposits pre-supposes "subsidence of large areas—regional subsidence as it may be called." If therefore great sedimentation is the cause of mountain-building, since subsidence is the cause of sedimentation, or rather its necessary accompaniment, then great depressions of the earth's crust must be looked upon as the ultimate condition or accompaniment of mountain-building; that is, a subsidence of the earth's crust is either the cause or accompaniment of a rising in the same locality, which is absurd As well might one say that the defeat of an army in one battle is the cause of its victory in the next; or that the greater the piles of dead in the one the greater the triumph that will follow.

Again, the author, in endeavouring to account for the subsidence, continues (page 270)—" If we assume, as we have reason to do, that "the heated interior of the earth below the crust, solid only by pressure, "is subject in large masses to change of volume by change of tempera-"ture, caused by re-combination [chemical combination?] of matter "taking place from time to time, many difficulties can be explained.

[1] Page 89.
[2] Page 90.

" An almost infinitesimal change of bulk, if the mass be large enough, " would explain what to our eyes seem stupendous movements." The author here asks for a great assumption, and one which, if granted, gives the necessary power to *upheave* as well as to *depress*. Change of volume by change of temperature is all that is wanted to account for the excrescences of the earth's crust which eventually form into mountain ranges. Where therefore, along with the assumption, is the necessity for the cumbrous machinery of great sedimentation, and rise of the isogeotherms, which the author makes the chief point in his argument? Even supposing great sedimentation had the enormous effect which the author advocates, it must cease to act when the sea level is attained. When, therefore, sedimentation has ceased, where is the power to urge those horizontal sedimentaries into the mountainous form? When they have attained the form of shoals or sandbanks, no further deposition can go on, and therefore (by the author's supposition that sedimentation is the great cause of upheaval) the isogeotherms would cease to rise, expansion of the lower beds would remain as it was, and there would be no further development of mountain-building forces. I see no way out of this difficulty unless it be by the rather grotesque assertion that mountains must therefore be formed subterraneously: a subterranean mountain, however, is somewhat of a contradiction in terms. I regard, therefore, this theory, that great sedimentation is the cause of mountain upheaval, as incompetent and self-contradictory.

Though it is like beating a corpse to say more, there is one simple way of refuting the theory which I may indicate. A thickness of eight miles of Cambrian and Silurian strata is urged by the author[1] as the sedimentation which brought about the upheaval of the mountains of Wales. Now, if eight miles of rock produced this effect, surely half that amount, or four miles, must have had an effect in some proportion; therefore, when four miles were laid down there ought to have been a mountain range asserting itself, not so high a one perhaps, but sufficient to stop all further sedimentation in that

[1] P. 30.

area. How then were the other four miles of strata deposited above them? Put briefly, the objection to the theory is this, that, if sedimentation had the effect claimed for it, it would very quickly defeat its purpose by stopping sedimentation in that area.

Again and again we find the author declaring with fresh assurance that it has been proved that mountain ranges have been areas of great sedimentation. In answer to this I would urge that it is only in mountainous parts that great thicknesses of strata can be actually observed by us; and that we frequently know nothing of the depth to which the sedimentaries reach beneath the flat or gently undulating areas of continents.

Finally, even if great sedimentation should be proved to be a characteristic mountain feature, I should rather regard it as the effect than the cause of the mountains. Denudation acts more powerfully on a mountainous region than elsewhere, for obvious reasons. Thus, the sedimentaries might be thicker in the neighbourhood than far away. When, therefore, further upheaval of the mountain mass goes on, these strata will be incorporated with it, and fresh ones then deposited. The core of the mountain range in a rising area is ever being converted and redistributed in the form of fresh sediment round about the flanks, which then once more are upheaved. So that, as in the case of the Himalaya, the range continues growing by fresh additions to itself, like a coral, by the incorporation of its offspring with itself.

But leaving these generalizations, which I have shewn to be fallacious, let us turn to more concrete statements regarding actual mountain ranges. In Chapter V, Mr. Mellard Reade writes—"It has "been a subject of wonder to more than one eminent geologist that "all the greatest mountain ranges are, geologically speaking, so com-"paratively modern. The Himalaya, the Andes, the Alps and the "mountains of the Caucasus have been to the larger extent upheaved "in Tertiary times." The reason he gives for this is that the youngest mountain ranges have been less exposed to destructive denudation, which has, on the other hand, almost levelled all the ranges of moun-

tains which were crushed up during the earlier periods of the earth's history. A few lines further he adds—"this great truth remains that "it is impossible to point to a range of mountains which have been "built up of old denuded rocks. Old rocks certainly accompany and "form part of all great mountain-ranges; but they are only discover- "able through the removal by denudation of the enormous masses of "more modern sediment with which they were originally covered. . . " . . . If we could point to *one* example where a mountain-range had "been built up solely of old rocks that had long suffered denudation, "and remained at their upheaval uncovered by newer sediment, the "significance of this association of great sedimentary deposits with "mountain-building would be considerably weakened."[1]

Among particular examples in illustration of the above principle he says, referring to India, that the "Tertiary [system] alone, "measuring 30,000 ft., has been upheaved and carved by denudation "into the greatest mountain system of the globe—the Himalaya."[1]

If it be borne in mind that the principle and the supposed facts alluded to here by the author form an important part of his reasoning throughout the whole of his work, it will be seen how necessary it is that there should be no doubt whatever of the validity of either the principle underlying his argument, or of the facts that he brings forward in support of it.

Now, with regard to the greatest mountain-ranges being, geologically speaking, comparatively modern; there is one consideration which the author does not seem to have taken any account of, namely, that to begin with a mountain-range must grow; and that we should therefore expect to find some mountain-ranges, not yet completed, which would be still more modern and of very low elevation. It has been pointed out by Prof. Judd that the life history of crystals in many respects bears a great resemblance to the life-history of animals and plants: they have their time of birth, of growth to maturity, and their ultimate decay and disintegration. And, without adopting

[1] Page 30.
[2] Page 73.

any theory or prejudicing any, it seems to me that a mountain-range must have in some sort a life-history, which may, in common with that of animals, plants and crystals, be divided into periods of growth, of maturity, and of decay. Long ago, as the result of the principles established by Sir Charles Lyell, cataclysms such as would heave a mountain-chain into immediate being have been discarded as preposterous fables only fit for the childhood of geology. Whatever be the view of the cause and the mode of working of the forces which wrinkle up the earth's crust into the majestic plications forming most of the larger ranges of the world, there is but one unanimous opinion that it came about gradually and not abruptly. But in this process of growth a mountain-range is opposed by the action of denudation. It therefore follows that, if a mountain-chain is to rise at all, it must be by its inherent growing forces, whatever they may be, ever becoming more and more intense and winning in the struggle with the opposing forces of denudation ; and it also follows that, if ever a mountain-chain is to succumb to the levelling processes embraced by the general term denudation, it must be by the inherent growing forces of the mountain having reached their maximum, and having in turn become feebler and feebler until finally they are altogether extinct, and the once stupendous mountain is worn down to the level of the sea.

So far I have no doubt Mr. Mellard Reade will go with me ; he, in common with every one, must admit that the loftier mountains of the world must be at, or near, their maturity ; whilst those of less altitude must be either on their way to become more lofty, or must be declining after having reached their maximum of elevation :—*herein lies the real difficulty, namely, to distinguish between a mountain-range progressing towards full development and one retrograding towards extinction.*

It therefore seems in the highest degree improbable that the greatest mountain-ranges are, geologically speaking, comparatively modern. On the contrary, we should expect that being at the period of their fullest development they must be, geologically speaking, of

decidedly mature age. If we wish to see the aspect of a comparatively modern mountain, we have only to look at some cases which admit of no doubt, such as the chalk wolds of Yorkshire and Lincolnshire, which must have been elevated and slightly disturbed previous to the Post-Tertiary deposits of the low country nearer the sea. There we have an example of what can be accomplished in the lapse of time between the beginning of the Tertiary period and that of the glacial epoch. The Pennine Chain may next be cited as an illustration of a mountain-range which is older than the chalk wolds, but which is probably still in the process of growing. It has been subject to the elevatory forces of crushing and folding during Secondary and Tertiary times; and has been successively wrapped round on its east, west, and south sides by new formations; all of which have in turn been elevated, in order and degree, more or less directly proportional to their age. The Pennine Chain is more elevated and more folded than the chalk wolds; and this seems to be simply because the forces have had a longer time for working in in the former than in the latter case. Finally, the older Palæozoic rocks rise into the highest form of mountain structure which we have in England. On the other hand, much of the older Palæozoic country of Wales and the Lake district is lower than that of the Pennine Chain; and the reason for this is perfectly evident. High as are some parts of the Cambrian and Silurian area, it is probable they are not so high as they once were. These mountains would seem to be retrograding towards extinction; denudation is gaining on the forces of upheaval, so that in parts they have sunk to a lower level than the growing area of the Pennine Chain.

Let us now examine the next paragraph quoted by me. Mr. Mellard Reade says—"it is impossible to point to a range of mountains "which have been built up of old denuded rocks." I find it difficult to understand the form of thought which could induce such a statement. Unless there be some hidden meaning in the words "built," "old," or "denuded," I should regard the very opposite of this statement as the great residual truth. Using words in their plain significance,

I think few will doubt that every large mountain-chain is built up of a body of Palæozoic and crystalline rocks, merely flanked and sometimes partly covered by Secondary and Tertiary rocks ; whilst, on the contrary, non-mountainous country is, as a rule, composed essentially of the younger formations. Continuing the quotation above, we learn that "old rocks certainly accompany and form part of all mountain-"ranges ; but thay are only discoverable through the removal by denu-"dation of the enormous masses of more modern sediment with which "they were originally covered." He illustrates this by pointing to India and saying "the Tertiary (system) alone, measuring 30,000 ft., "has been upheaved and carved by denudation into the greatest moun-"tain system of the globe—the Himalaya."

To the uninitiated reader the above remark would at once raise the belief either that the only rocks found in the Himalaya were of Tertiary and Recent date, or that older rocks, if found at all, would only be discovered in the bottoms of ravines cut out by river erosion, or along anticlinal axes : it would most certainly invoke a vision of the Himalaya roughly blocked out of Tertiary strata. Now, what is the real state of the case ? Over the greater part known to us it is this : the Himalaya, rising to about 25,000 feet in height, are composed chiefly of ancient gneissose granites, gneisses, granulitic gneisses, and crystalline schists down to a level of about 10,000 feet. Below that, over a vast area called the Lower Himalaya, there are chiefly quartzites, quartz-schists, traps and slates down to the 3,000 feet level. There is then a narrow band of rocks averaging only about 12 miles wide lying between the 3,000 feet level and the plains, which is in reality composed of Tertiary rocks, namely, those forming the subject of this memoir. If we could survey the Himalaya from some great height above them, and a cataclysm were to take place completely obliterating the Tertiary rocks, we should be quite unconscious of it. It would in fact be a mere flea-bite to the Himalaya as a whole.

Ridged one behind and above the other, the Tertiaries may be said to rise from the plains in height and distance according to their

antiquity, the oldest being highest and further away. They are a series of steps formed in a measure like the gravels of a river-bed which are left by the cutting of the channel, at heights proportional to their ages, but, unlike them, depending for their different elevations not on the sinking of the plains but on the further crushing up of the Himalayan area.

In Chapter V I have sufficiently disposed of the view that they can ever have extended to any appreciable distance beyond their present areas into the Higher Himalaya.

The intermittent deposition, therefore, of 16,000 feet of them at the margin of the Himalaya was certainly not the cause of the upheaval of the Himalaya. On the other hand, it was due to movements of the mass of the Himalaya themselves that they owe their present elevated and compressed state. They therefore were the sufferers by, and not the originators of (except in an indirect sense to be presently mentioned), a continuing upheaval of those mountains, be that movement due to whatever far-reaching cause it may.[1]

But I have already occupied too much space in this connection and must take leave of Mr. Mellard Reade's book, which, with the exception of the doctrine taught, is an admirable colligation of facts from many lands about mountain structure.

The Rev. O. Fisher's "Physics of the Earth's Crust."

There is one other recent work of a theoretical nature, about which I should like to say a few words. It is a pleasure to turn to the Rev. O. Fisher's "Physics of the Earth's Crust," a treatise published in 1881; for, as regards many of the subjects discussed in it, I feel myself entirely on his side. Opinion may be divided concerning some of the quantitive results that he has obtained by mathematical methods o treatment; but every one must admire his lucid and correct reasoning on the facts which he takes for granted. He makes two geological references to the Himalaya, which I may here quote, for it will be

[1] Since writing the above I find a somewhat similar position taken up by Dr. C. Ricketts (Geol. Mag., April 1889), with reference to Mr. Mellard Reade's theory. In addition, he concludes by expressing a belief in the permanence of the "core of the mountains" of Britain through many oscillations of upheaval and depression.

shewn that the views he enforces by these Himalayan examples are still more completely borne out by the results obtained by me.

His first reference is introduced by way of shewing that the crust of the earth in mountain regions has suffered lateral compression as distinguished from vertical up and down movements. He writes, p. 43,—" To take an instance of the mode of action of lateral pressure, " we may refer to the very instructive comparison between the Alps " and the Himalayas which has been made by Mr. Medlicott and pub- " lished in the 'Journal of the Geological Society'.[1] He there shows " that the reversed apparent faulting by which the older rocks of the " central chain of the Himalayas appear to overlap the younger of the " Nahan range, and these again the still younger rocks of the Siwalik " range, is due to lateral pressure, which must have compressed the " rocks horizontally, at least at two distinct epochs since the central " chain was first elevated." From what I have said in previous chapters on the subject of the five reversed faults in the Pelâni R., and their formation at successive periods, it will be seen that at least in that locality five distinct compressions have acted, resulting in horizontal thrusts of the growing mountain mass towards the plains. The Sub-Himalayas, therefore, are really richer in examples of lateral pressure than Mr. Fisher supposed when he wrote his book. If he had produced it a few years later, he would have been able to add the very striking examples of horizontal thrusts that have lately been worked out with great patience and skill in the north-west highlands of Scotland by Prof. Lapworth, Messrs. Peach and Horne, and other officers of the Geological Survey of Scotland. Still, in drawing that inference from the Himalaya, he drew one which further work among those mountains has only succeeded in making the more apparent.

His second reference includes the Himalaya as evidence against the theory of the entire solidity of the earth. The instability of the earth's crust, the shifting of the crust towards a mountain range, and the sinking of deltas and other regions of deposition, go to shew

[1] Vol. XXIV, p. 34.

that the crust is in a "condition of approximate hydrostatical equili-"brium, such that any considerable addition of load will cause any re-"gion to sink or any considerable amount denuded off an area will "cause it to rise," and, therefore, that there must be a "fluid substratum" on which the crust floats. He writes, p. 80,—"The Himalayan "area presents some peculiarly interesting features in this connection. "The Sub-Himalayan range consists of tertiary strata which are now "highly disturbed. All, with the exception of the lower portion, which "is nummulitic and consequently marine, are composed of sub-aërial "deposits, formed by detritus brought down by torrents from the "Himalayas. These deposits are together between 12,000 and 15,000 "feet thick. The sandstones, which form the chief portion of these "beds, and the red clays which are intercalated with them, are exactly "like the alluvial deposits of the plains. 'Thus it was suggestive, and "not altogether misleading, to say that the Siwaliks were formed of an "upraised portion of the plains of India.'[1] The surface movements in-"dicated by this history suggest a level area at the foot of the Hima-"layan range, sinking continuously during the former part of the "tertiary period. Then a great movement of lateral compression and "elevation took place. Again it sunk, and unconformable beds were "deposited. These were again elevated and compressed. Such at "least appears to be the interpretation of the description given by "the surveyors. But the point which is material to our present subject "is the sinking of the land surface to the depth of nearly three miles, "while river deposits to that thickness were being laid down; the "whole being denuded off mountains whose spoils have in more recent "times provided materials for the great plains of India, and still "those mountains stand the highest in the world. That a sinking of "the area of the plains of a similar character is yet in progress, is "shown by the boring at Fort William, near Calcutta, in which to "the depth of 400 feet fresh-water deposits occurred. The con-"clusion seems irresistible that corresponding to the long, though "occasionally interrupted, depression of these plains, a correlative

[1] Manual of the Geology of India.

"elevation of the great range which has supplied the deposits has "been going on."

I need scarcely remark that the tendency of the general results which I have obtained is to strengthen this conclusion. I have shown indisputably that the margin of the Himalaya in all ages of the Tertiary period has been a line of weakness advancing slowly towards the south; on one side of which the strata have been thrust southwards and upwards, and on the other side of which they have been thrust northwards and downwards. And not only this but I have given proof in the section south of the Sanguri sót, and in those north of the Sára N., that the sinking of the plains and the rising of the hills was not an alternating phenomenon as if the one were the forward and the other the backward swing of a pendulum, but that both went on at one and the same time.

Therefore, by the regularity of the folds and the fold-faults which have affected the Sub-Himalaya, by their parallelism, and by the parallelism and uniformity of elevation and aspect of the different zones between them, by the regular succession of the fold-faults in time through all the ages of the Tertiary period, and by the presence of one in the act of forming between the Recent deposits of the plains and the edge of the hills, it is abundantly evident that further additions of sediment at the foot of the mountain-land was always accompanied by a sinking of that part and a rising of the denuded area, through the whole of the Tertiary period, and probably through the individual ages represented by each rock stage.

Recent Himalayan research, therefore, in this direction goes to establish the fact that the crust of the earth is extremely sensible to changes of load on it, that it rises when relieved, and sinks when over-burdened; and that, therefore, we must adopt some such supposition as that of the author of the "Physics of the Earth's Crust," namely, that a "fluid substratum" exists at some depth beneath the surface in which that crust floats in approximate hydrostatical equilibrium.

Index to Horizontal Sections.

r = Recent.

d = U. Siwalik Conglomerate	Siwalik series	Sub-Himalayan System (Tertiary).
c = M. Siwalik sand-rock		
b = L. Siwalik Nahan sandstone		
a = Nummulitic	Sirmur series	
n = Tál series	Mesozoic	Younger Himalayan Sub-Group (Mesozoic)
m = Massive Limestone	Age unknown	
x = Purple slate	Age unknown	Older Himalayan Sub-Group (Palæozoic?)
y = Volcanic breccia	Do.	
z = Crystalline schist	Do.	

t = Trap.

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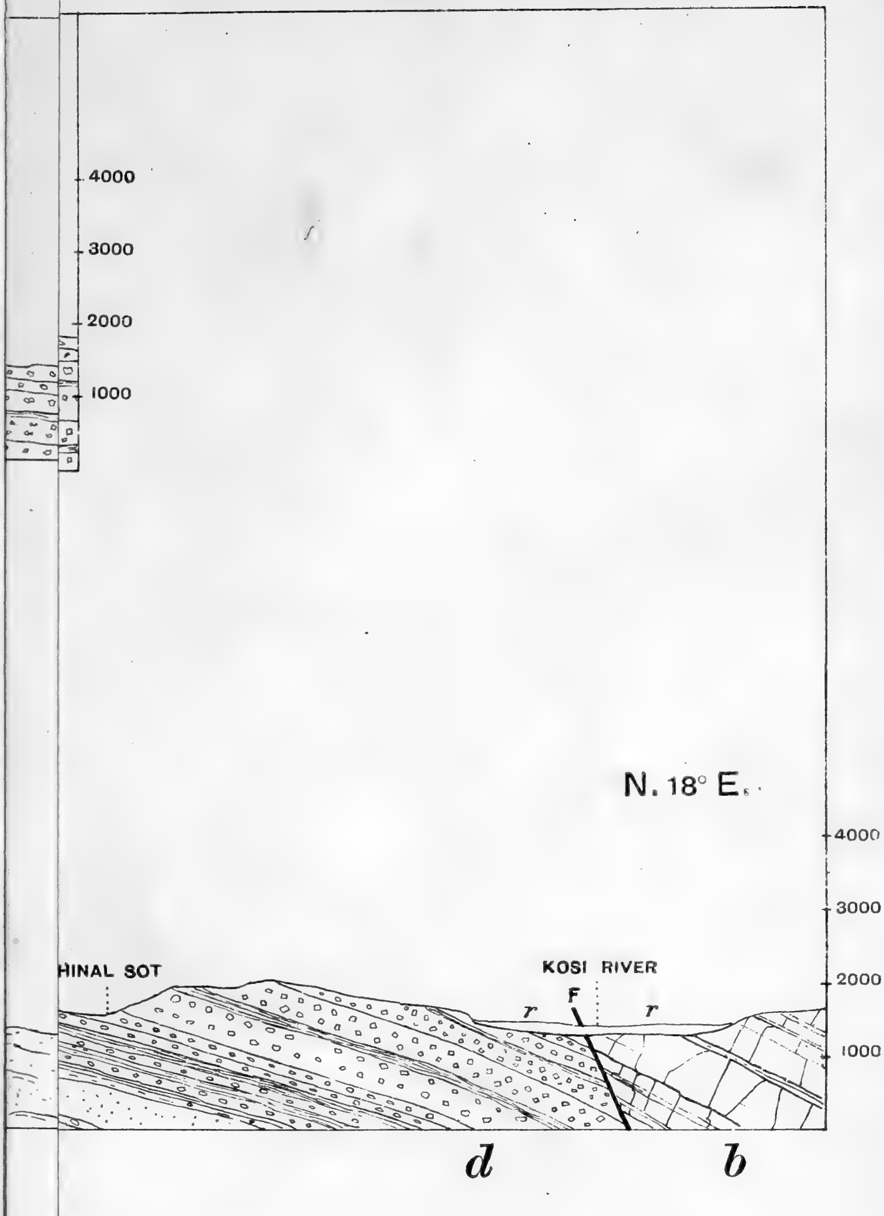
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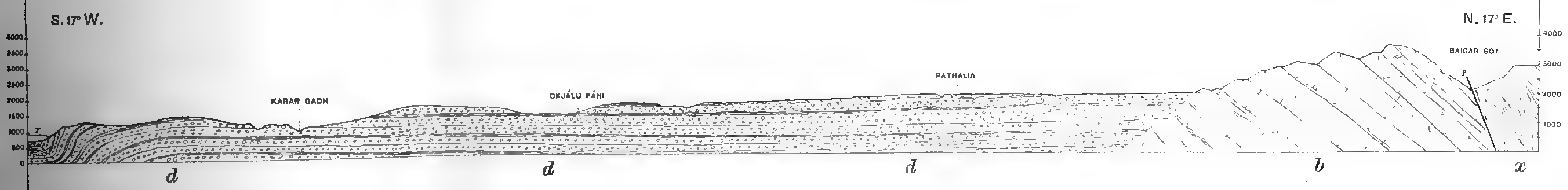

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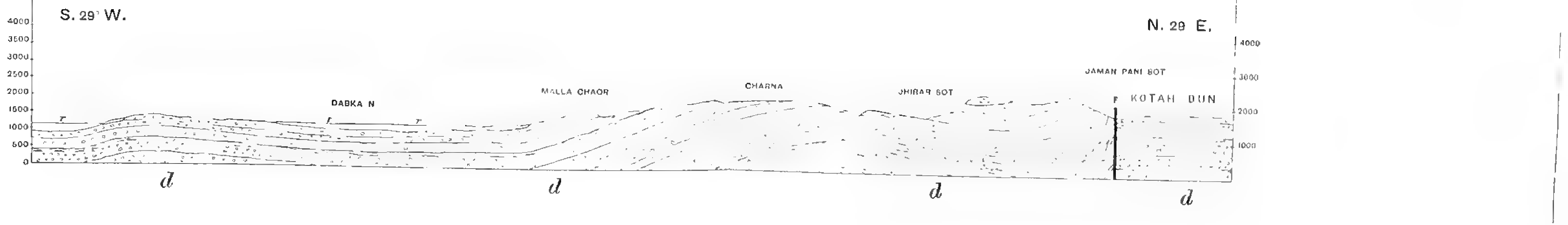

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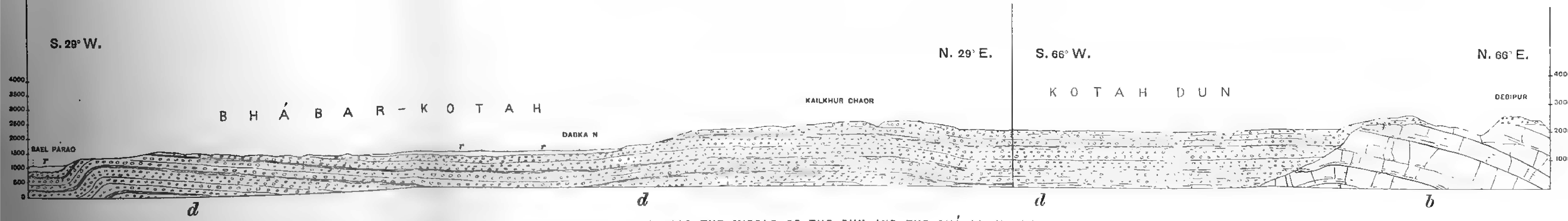

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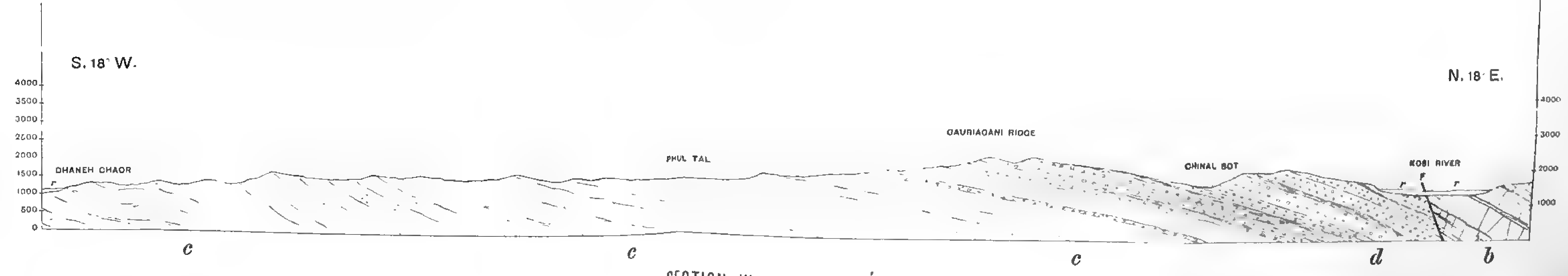

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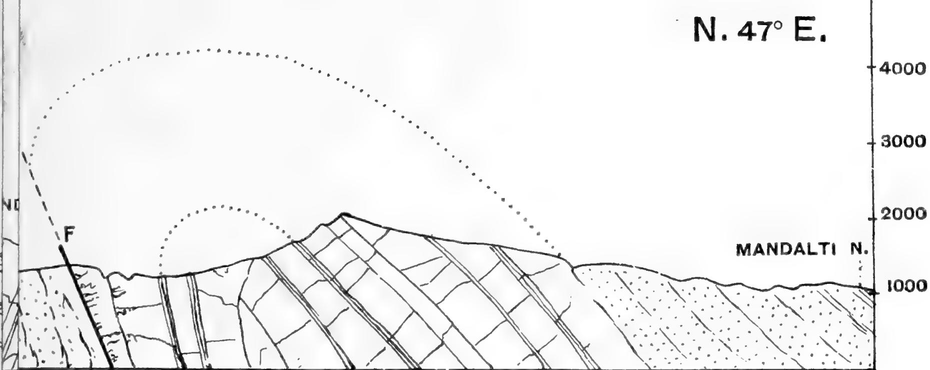
Horizontal and Vertical Scale, 2 Inches = 1 Mile.

Lithographed at the Survey of India Offices, Calcutta, December 1890.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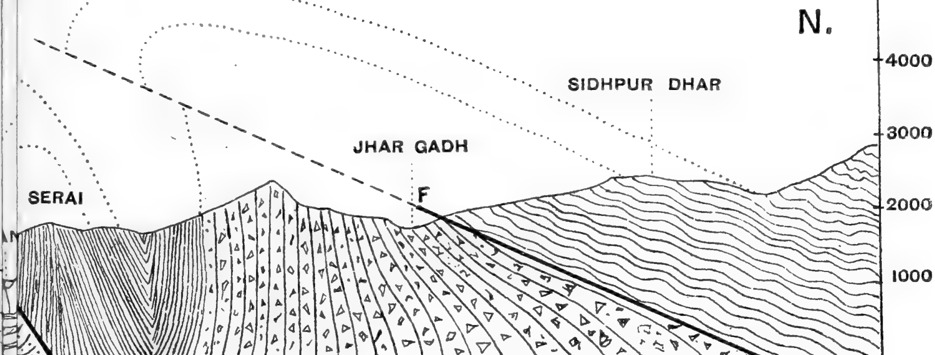
MANDALTI N.
F

b *c*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SIDHPUR DHAR
JHAR GADH
SERAI
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HORIZONTAL SECTIONS. SHEET II.

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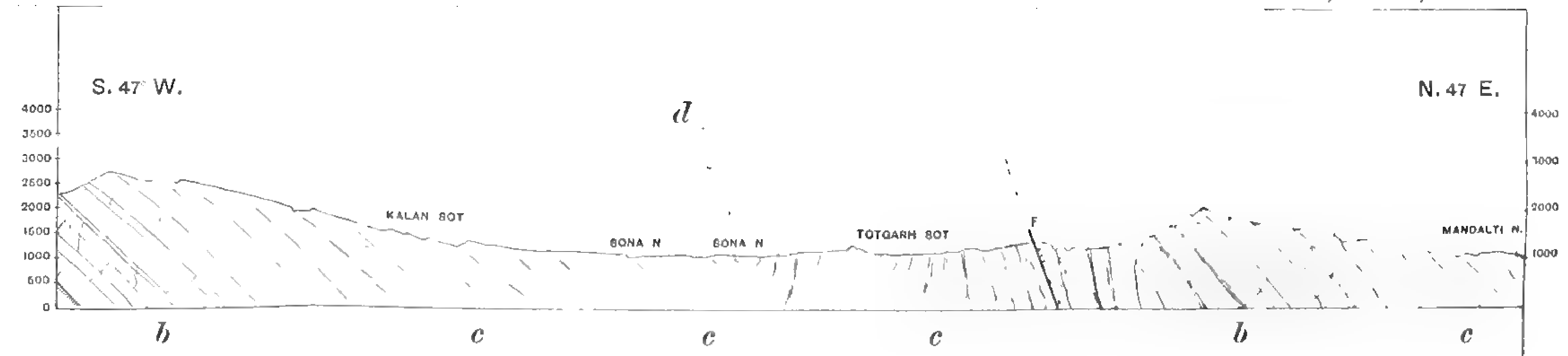

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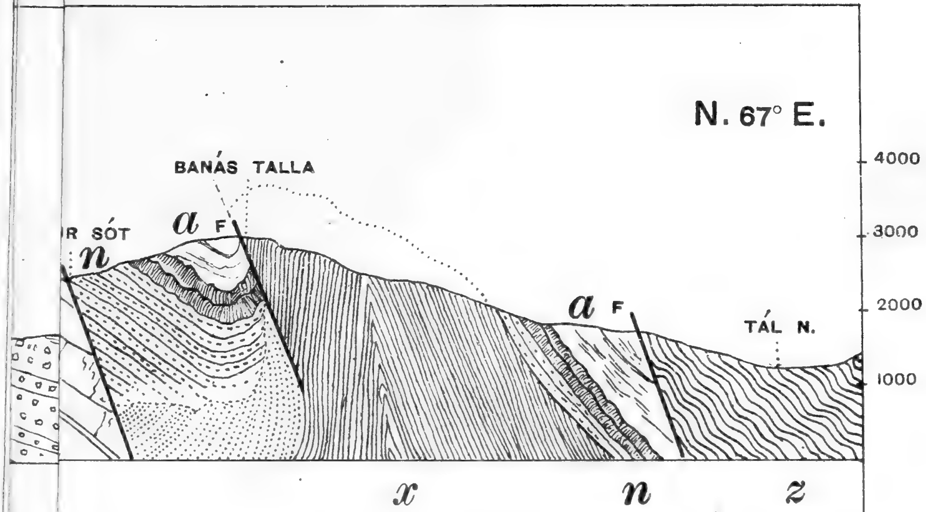

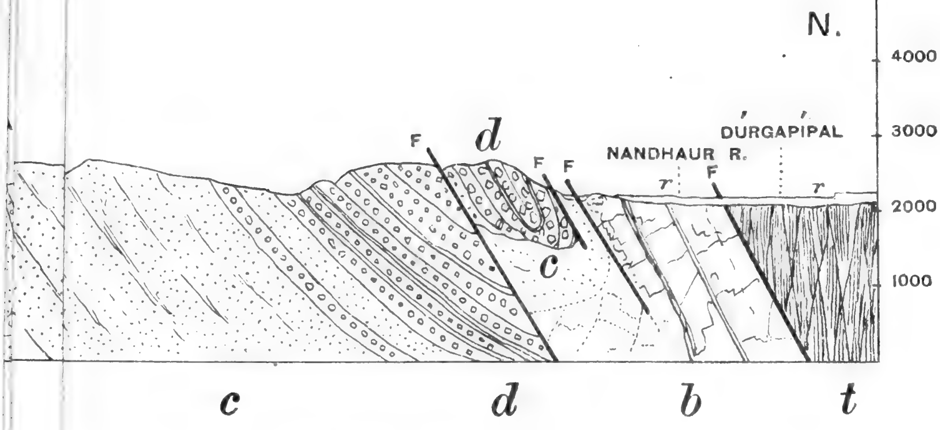

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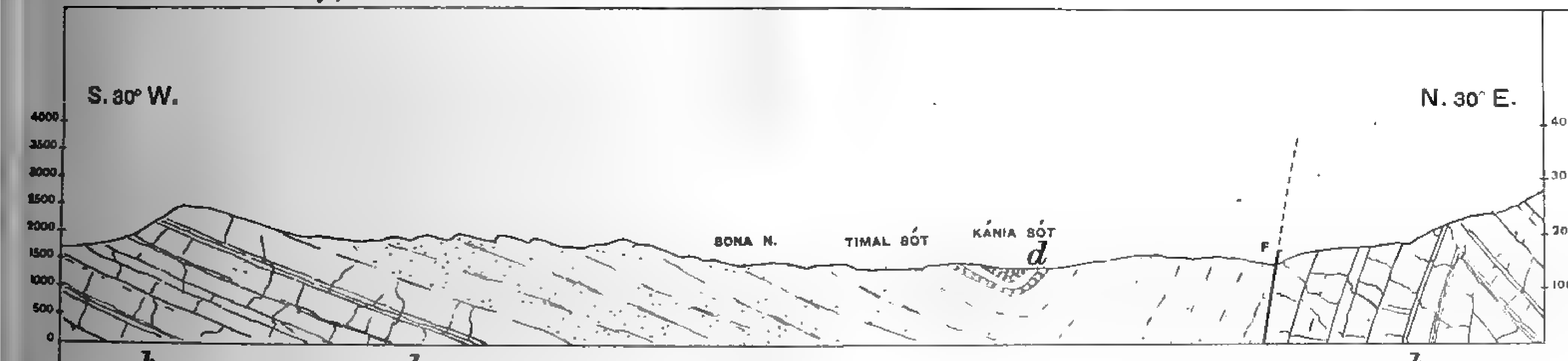

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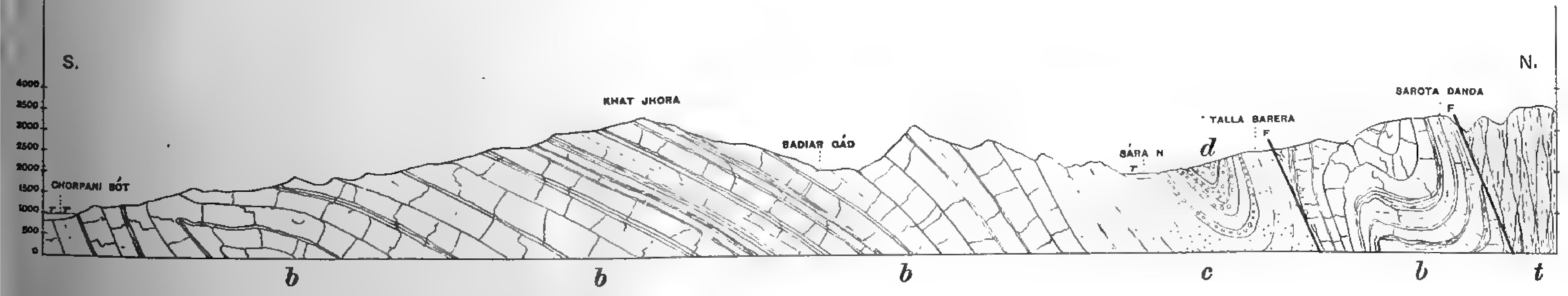

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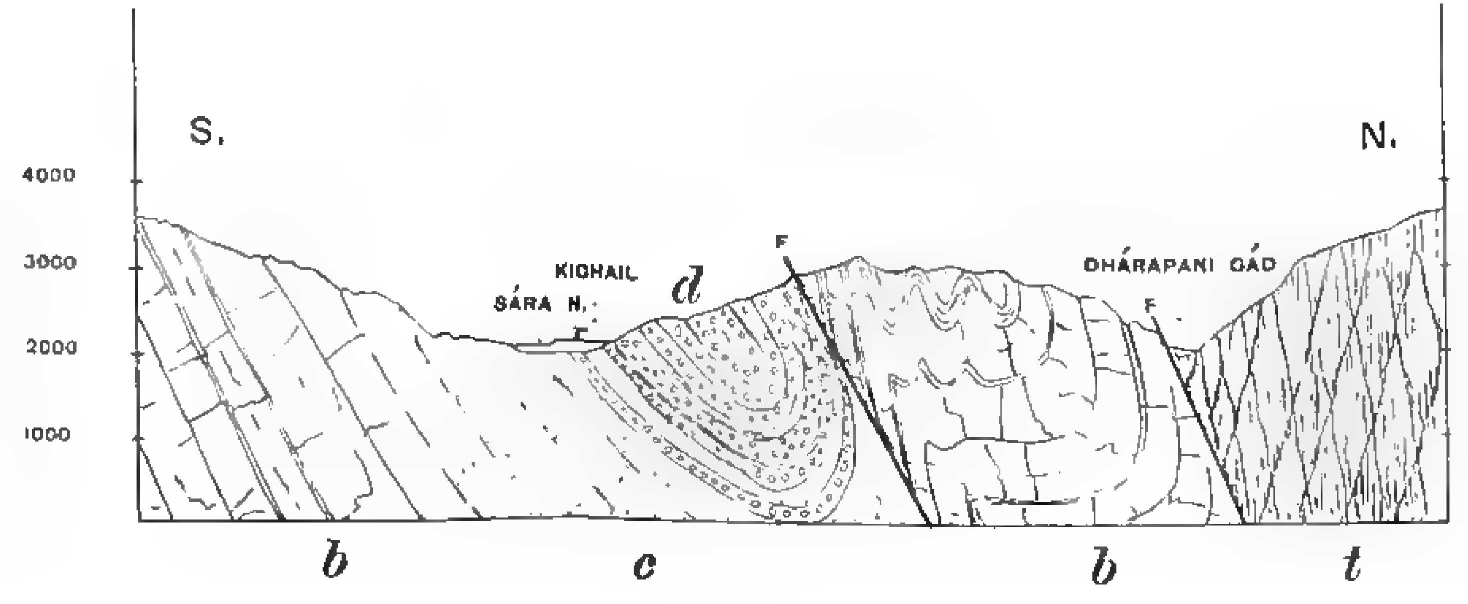

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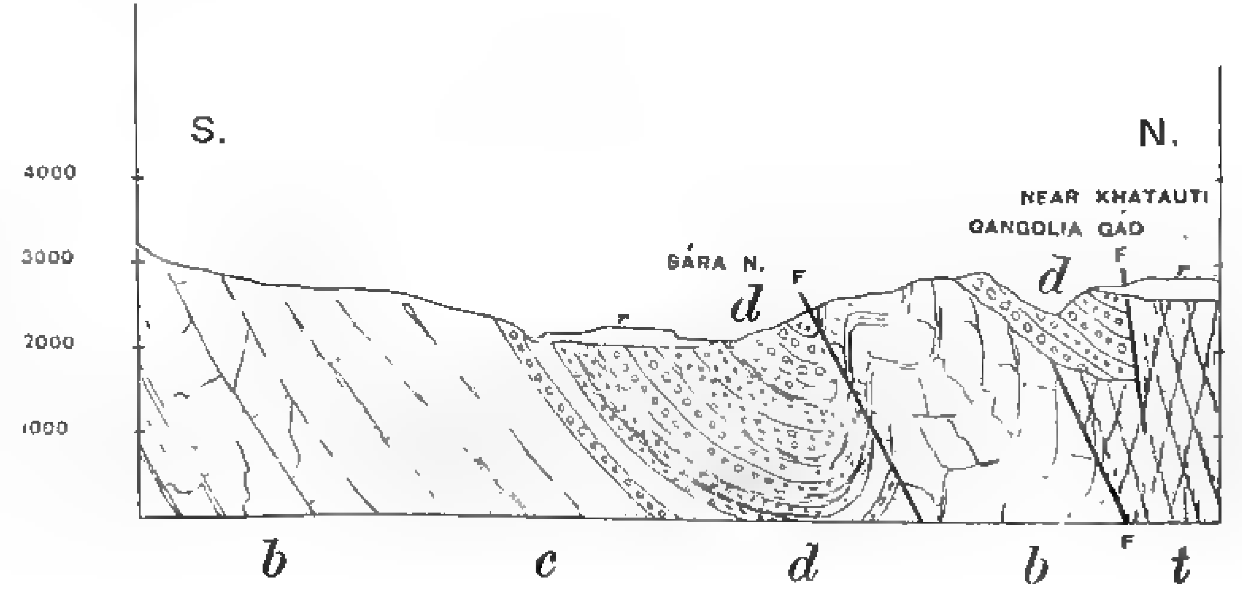

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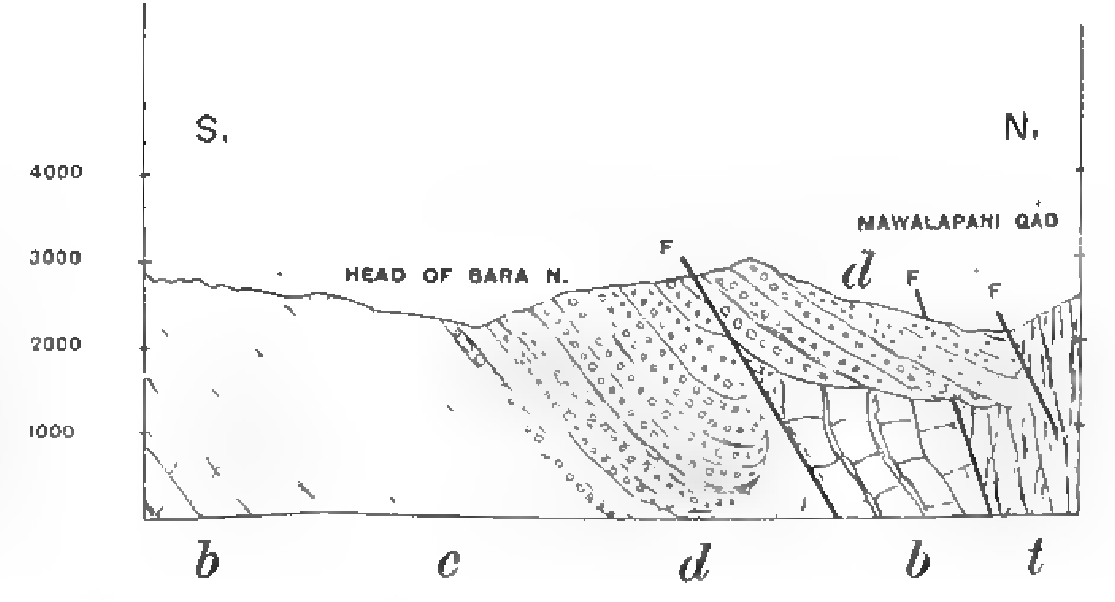

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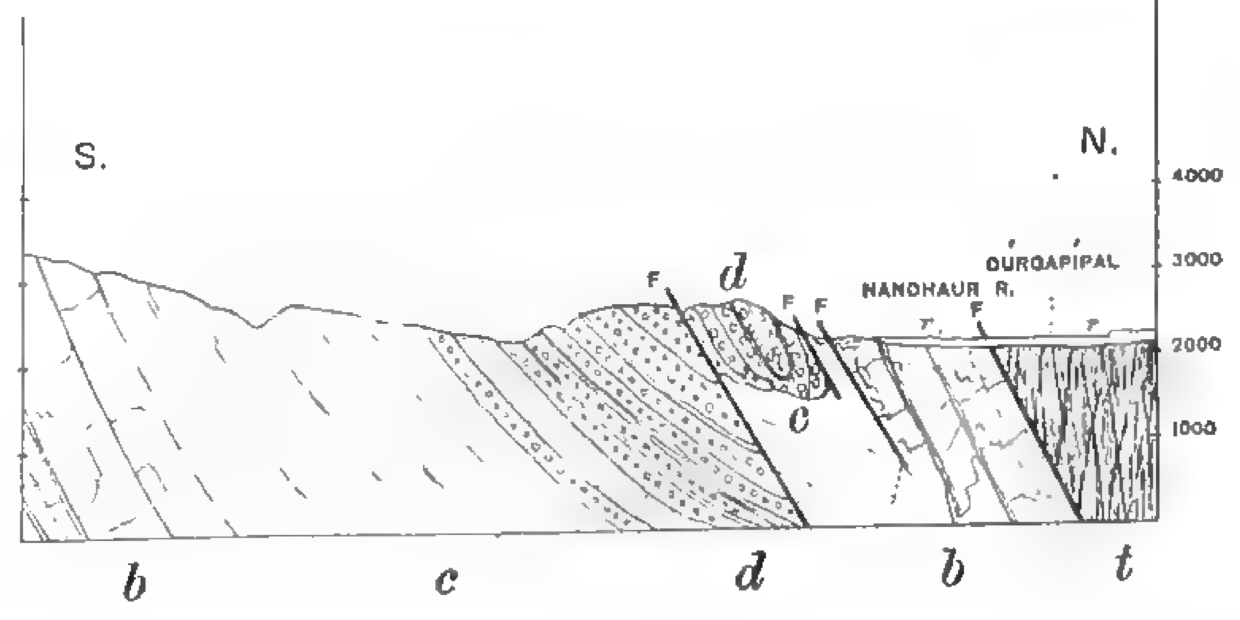

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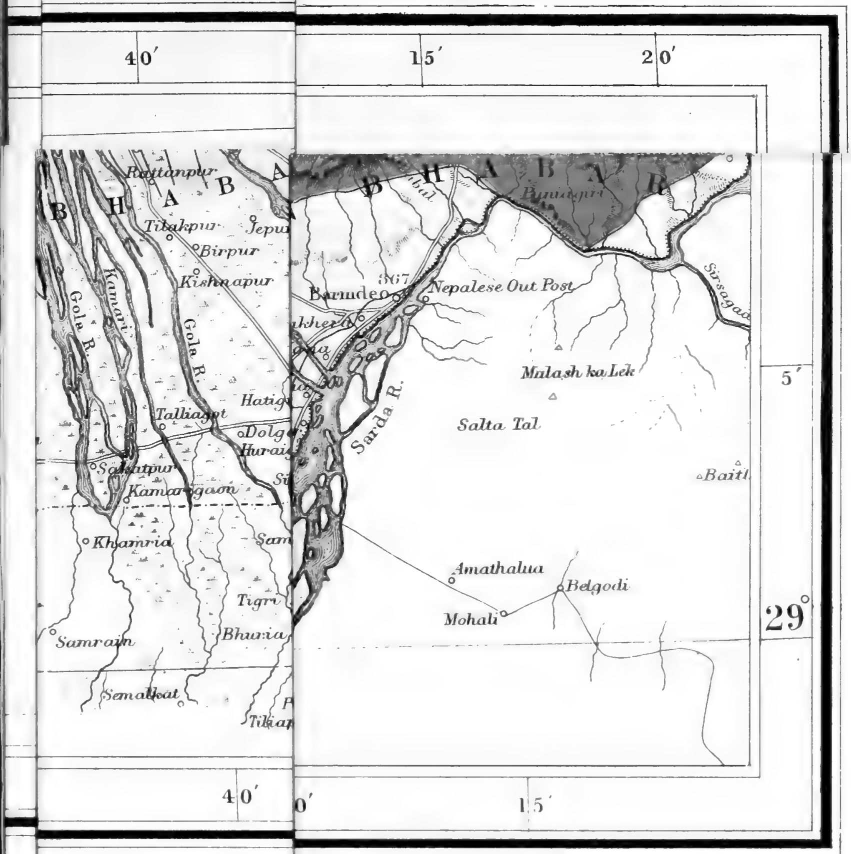

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Taken from Sheets Nos. of the Atlas of India.

Lithographed at the Survey of India Offices, Calcutta.

MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

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VOLUME XXIV, Part 3.

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MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA.

THE GEOLOGY OF SOUTH MALABAR, BETWEEN THE BEYPORE AND PONNÁNI RIVERS, *by* PHILIP LAKE, B.A., F.G.S., *Geological Survey of India.*

INTRODUCTION.

THE portion of Malabar to be described in this report lies, for the most part, between the Beypore[1] and Ponnáni Rivers, and stretches from the sea on the west to the Ghâts on the east. The Western Ghâts are here much further from the coast than they are to the north and south, so that South Malabar lies in a sort of bay. To the north of this bay are the Wynaad Hills, which reach to within a few miles of the sea. To the east are the Nilgiris and Pálghát Hills, which are 40 or 50 miles from the coast. To the south the Western Ghâts (Cochin Hills) again draw nearer to the sea and form the southern boundary of the "bay."

Topography.

The coast is low and sandy, with a few reefs of laterite at the mouths of the Kadalhundi and Beypore Rivers. There are narrow backwaters and some wide marshy tracts that lie nearly at the sea-level; but the whole backwater system is very small compared with that of Travancore. It is in this region that cocoanut palms are most numerous; and it is probably by the binding power of their roots

[1] In this paper the rivers are named after the chief towns at their mouths, and tributaries after the chief towns on their banks.

that the coast is enabled to resist the attacks of the sea. Otherwise so loosely built a shore, resting, as this appears to do, on a very insecure foundation of mud, would always be subject to change.

The only place, however, where there seems to have been much change recently, is the island of Chāliyam. This island lies between the mouths of the Beypore and Kadalhundi Rivers, and is cut off from the mainland by a backwater connecting those two rivers. Dr. Buchanan states[1] that, when he visited the neighbourhood (December 1800), there was no connection between the two rivers. But he mentions that it is marked on Major Rennel's map. It is also marked, nearly as it at present exists, in the map of Malabar by Lieutenant Ward and Captain Connor. We may, therefore, conclude that Dr. Buchanan was mistaken, and that the backwater has been in existence at least since the date of Major Rennel's map.

The island of Chāliyam now consists partly of low lateritic hills and partly of marshes; and, according to some accounts, very rapid changes have taken place in these marshes. But as they lie almost level with the sea, and at the mouths of two rivers subject to floods, this is not surprising.

At a few other points near the coast there is evidence of some very recent alterations in the lie of the land; but the amount of these changes is small, and their importance slight.

It is, however, only recently (geologically speaking) that the coast has become at all fixed and steady. The whole of the backwater region has been under the sea since most of the Malabar laterite was formed; and not far outside the area under consideration, there have been very considerable changes within historic times.

Coastal region.

The coastal and low-lying region extends up the Beypore River, as far as Ferokh (Ferokkabad). Southward it is bounded on the east by the Kadalhundi River, as far as the point where the general direction of that river changes suddenly from west to north. South of this, the low land reaches to

[1] Journey through Mysore, Canara, and Malabar. Madras reprint, 1870. Vol. II, page 131.

about four miles from the coast; but about two miles north of Tanur a laterite-capped ridge, about 120 feet high, runs out to within a mile of the sea. South of this ridge the coastal area again widens out and runs inland to Tirur; and further south still it becomes very much broader, till north of the Ponnáni River, east of Kootye, it stretches about nine miles inland.

The land immediately to the east of the region thus defined rises suddenly to a height of 100 to 150 feet, and presents a somewhat cliff-like aspect to the sea. This cliff is the western edge of the laterite plateau of Malabar. But many valleys have been cut in the higher land, so that the cliffy edge of the plateau is very much broken; and the low-lying country runs in tongues up these valleys, far beyond the limits of the main coastal area.

Western part of the plateau ("undulating region").

The country to the east of the cliff is undulating, with low hills and shallow valleys. The rising ground between the valleys is about 120 to 150 feet above the sea near the coast; but its height gradually increases towards the east. The surface of the ground slopes gently down from the tops of these hills to the stream valleys between them. Figure 1, Pl. I., shows the undulating character of this part of the country. It is a section drawn from south to north through Kuttipáli ($11\frac{1}{2}$ miles from Malapuram on the road to Tirur Station).

Central part of the plateau.

As we go further inland, the high ground between the valleys, becomes higher, and the valleys become deeper with steep sides instead of gentle slopes, till at last we reach the highest part of the plateau, with valleys and gorges three or four hundred feet deep cut in it. Sometimes in this region a broad valley has first been cut in the plateau, and in the bottom of the valley a deep and narrow gorge is carved. At other times the sides of the valleys are terraced.

The kind of country just described is well seen near the military station of Malapuram (25 miles in a direct line south-east of Calicut). "New Malapuram" stands in one of the broad valleys, while the river flows some 200 feet below, in a deep gorge cut in the bottom of the

valley. North and south the laterite-capped hills of the plateau rise above the station (see fig. 2, Pl. I).

On comparing figures 1 and 2 it will be seen that the broad depression in which New Malapuram stands is analogous to the shallow valleys of the undulating region, and that the gorge has been excavated at a later date than the upper part of the valley.

Within an area which is roughly quadrilateral in shape, the four corners being at Urótmala, Pranakód Hill, Ananghât Hill, and the village of Kolattur (Collatore), the plateau rises to its greatest height, *viz.*, about 500 feet above the sea. On all sides it slopes downwards from this area—to 200—250 feet on the banks of the Beypore, and to 350 feet near Tritála, south of the Ponnáni River.

Within the region of the plateau with deep valleys, several gneiss hills rise abruptly to a considerable height above the plateau. The chief are (proceeding from north-west to south-east) Wallaiur Hill (about 700 feet), Kondotti[1] Hill, Urótmala (1,573 feet), Pandalur (about 2,000 feet), and Pranakód Hill (1,792 feet). The last three are all in the highest part of the plateau.

The plain at the foot of the Ghâts.

Further inland, the country again becomes undulating like that near the coast; but it is flatter and is really a plain with shallow valleys cut in it. This type of country extends to the foot of the Ghâts, the general level being broken only by irregular gneissic hills of no great height. It is 250 to 350 feet above the sea, and therefore much lower than the highest part of the plateau.

The whole of the country west of the Ghâts may, according to the description just given, be divided into four regions, *viz.*:—

(1) The coastal region.
(2) The undulating region (western part of the plateau).
(3) The gorge region (the highest or central part of the plateau).
(4) The plain at the foot of the Ghâts.

The first of these does not belong to the plateau at all, but forms a sort of ledge at the foot of the western edge of the plateau. The true plateau begins on the west with the undulating region, which is

[1] Coondoty of map—16 miles from Calicut on the road to Manjéri.

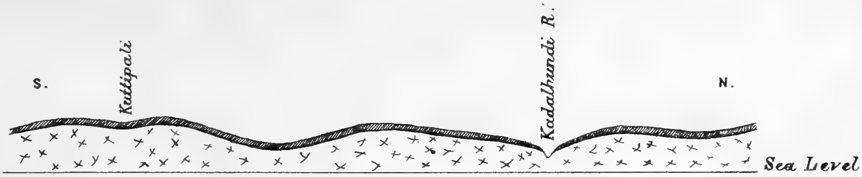

Fig. 1. Section through Kuttipali (E. of Ponmundum)

Vertical Scale 1 in. = 1000 ft Horizontal Scale 1 in = 2 m.

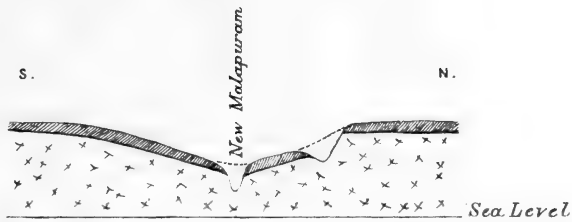

Fig. 2. Section through Malapuram gorge

Vertical Scale 1 in = 1000 ft Horizontal Scale 1 in = 2 m.

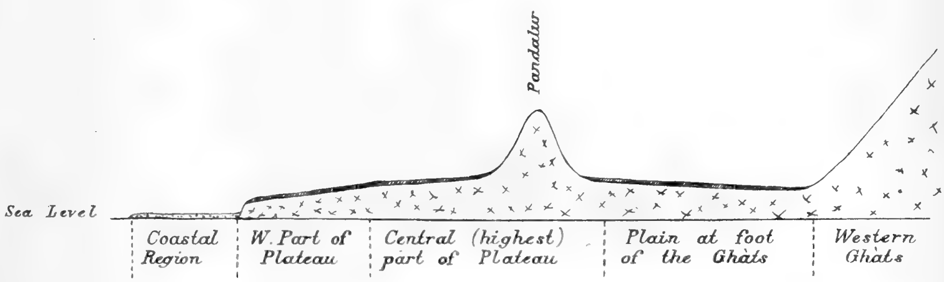

Fig. 3. Diagrammatic Section of S. Malabar

Plate. 1.

comparatively low. It rises gradually to the central region and then sinks towards the foot of the Ghâts. This is shown diagrammatically in Fig. 3, Pl. I, in which the stream and river valleys are omitted. Section I, Pl. VIII (near Tanur to Manarkád) shows the present state of the plateau, cut up in every direction by valleys.

The plateau slopes from its central point (about Pandalur Hill), not only to the west and east, but also to the north and south. The slope is very gentle, rarely greater than a quarter of a degree. Towards Ariakód (on the Beypore River) and towards the coast, the angle of inclination is about 15′ to 18′, and it probably never exceeds 18′.

The resemblance to a plain of marine denudation is perfect, the highest part being in the neighbourhood of Urótmala, Pandalur, and Pranakód Hill, which must have been islands before the plateau began to rise above the sea.

If the whole country sank about 500 feet, these hills would be islands lying in the middle of a bay, the coast being at the foot of the Western Ghâts. This was no doubt the condition of Malabar before the laterite period. As the land rose, a ledge formed round the chain of islands (Urótmala, &c.); and this ledge gradually grew outwards till it reached the Ghâts. The plain of marine denudation started from these islands as a centre. On other parts of the west coast, where there were no bays and no outlying islands, the plain probably started at the foot of the Ghâts and grew outwards to the west. In those places, therefore, the plateau slopes from the Ghâts to the sea.

Rivers.

The highest part of the plateau lies in the centre of the area described, and is separated from the hills on the north, east, and south (the Wynaad, Nilgiris and Pálghát Hills, and the Cochin Hills) by lower land, forming a ring-shaped depression or moat round it. The Beypore and Ponnáni Rivers flow in this moat and receive tributaries, the former from the south and the latter from the north, which flow round the eastern side of the central high land; so that this high land is almost surrounded, except towards the sea, by the basins of these two rivers. The chief drainage of the high land itself finds its way into the Kadalhundi River, which takes its rise in Pranakód Hill.

The Pandikád River is the only one that rises to the east of the central high land and cuts its way straight through. There is reason to think that, in former times, this river, like all the others rising in the Ghâts, also flowed in the ring-shaped moat. It probably fell into the Beypore River to the north.

The three greater rivers already mentioned, *viz.*, the Beypore, Kadalhundi, and Ponnáni, receive the whole of the drainage of the area. The Beypore is formed by the junction of a large number of streams in the Nilambur Valley, some of these streams rising in the Nilgiri plateau. The Kadalhundi receives only one important tributary, *viz.*, the Pandikád River, the Angádipuram River being really the main branch and not a tributary. The Ponnáni receives a great number of streams before entering this area; but in the area under consideration, the only important tributary is the Tudhakal River.

All these rivers flow throughout the year. They become very shallow in the hot weather, but never dry up.

Climate.

The climate of Malabar is very damp. The average annual rainfall is about 156 inches, of which about half falls in the months of June, July, and August during the South-West Monsoon. The driest months are January and February.

Forests.

Owing to the nature of the climate and the character of the soil, forests are very large and important. Trees and bushes cover almost the whole of the gneissic area; but cannot gain a footing on the older laterite. Fresh laterite, such as is found in the valleys, is not unfavourable to the growth of underwood and even of large trees; but the finest forests are found near the Ghâts. All the slopes of the hills, except those too steep to support soil, are covered with trees; while the tops of the ridges (in the Silent Valley and Pálghát Hills) are mostly grass-covered. The whole of the Nilambur Valley, an area of some five hundred square miles, is filled with lofty forest, of which a magnificent view may be obtained from Nilambur Hill.

The occurrence of these large forests and especially of very thick underwood adds considerably to the difficulty of the survey of the

country; but the bareness of the older laterite plateaux to some extent compensates for this.

Previous Observations.

The gold and iron ores of Malabar have at various times attracted considerable attention; but the general geology of the district has hitherto not received more than a passing notice.

Buchanan.

Towards the end of the year 1800 Dr. Buchanan passed through the southern part of Malabar, and he has left several notes on the geology of the district.[1] He describes the occurrence of granite and of "indurated clay" overlying the granite. To the indurated clay he gives the name of laterite, apparently because "in several of the native dialects, it is called the brick-stone (Itica cullu)." It is in his journal for December 20th and 21st, when he was staying at Angádipuram, that he first uses the word. He does not appear to distinguish between the two varieties of laterite.

He mentions the occurrence of iron ore at Colangode (which is outside of our area) and in Vellater; and of gold at Nilambur.

Newbold.

In 1840[2] Captain Newbold described a carboniferous stratum near Beypore. He seems inclined to refer it to the coal-measures and the laterite to the new red sandstone.[3] A note by General Cullen is added to his paper.

In 1845[4] Captain Newbold gave an account of a journey from Pondicherry to Beypore through the Pálghát gap. He mentions the occurrence of gneiss and laterite at various places, and of lignite and mineral copal at Beypore and Tritála.

In the District Manual of Malabar, there are a few notes of well sections and borings at various places in the district.

[1] Journey through Mysore, Canara, and Malabar. Madras reprint. Vol. II, pp. 49 *et seq.*

[2] Madras Journal of Lit. and Sci., XI, 239—243 (1840).

[3] In his later papers Captain Newbold appears to have recognised the recent origin of these deposits.

[4] Journal of the Asiatic Society of Bengal, XIV, 759—782 (1845).

The gold of Malabar first attracted the attention of the East India Company in 1792-93, and since then various reports and papers have been written on the subject,[1] but it is only necessary to refer to those of Lieutenant Nicolson,[2] who examined the country in 1831. His report is accompanied by a map in which he marks gold mines in the valley north of Ariakód, at Canpul (Kapeel of the Atlas sheet) near Nilambur, and near Pandikâd. Other mines lying outside the area included in the present report are also marked on Lieutenant Nicolson's map.

Gold.

Most of the later reports on the gold of Malabar confine their observations to the Wynaad and the Ghâts and do not refer to the area surveyed.

The native iron works were noticed by Dr. Buchanan, and since his time attempts have been made to establish iron works on a large scale at Beypore.[3] But these attempts failed, chiefly from want of fuel.

Iron.

Geology of the area.

The rocks found in the area, whose physical features have just been described, may be grouped as follows (in ascending order):—

(1) Gneiss—(*a*) Quartzose gneiss.
(*b*) Garnetiferous gneiss.
(*c*) Quartzo-felspathic gneiss.
Intrusive dykes and sheets.
(2) Laterite—(*a*) Plateau laterite.
(*b*) Terrace laterite.
(*c*) Valley laterite.
(3) Recent deposits.

[1] References to these will be found in Mr. Brough-Smyth's "Report on the Gold Mines of the South-eastern portion of the Wynaad and the Carcoor Ghât," Madras, 1880; and in the Manual of the Geology of India, Vol. III, pp. 180 *et seq.*

[2] Brough-Smyth *loc. cit.* Appendix; also Madras Journ. of Lit. and Sci. XIV, pp. 154—187.

[3] Manual of the Geology of India, Vol. III, p. 351.

Gneiss.

The gneiss of the area under examination is almost everywhere very fine-grained and usually well-laminated. The chief minerals found in it are quartz, felspar, hornblende, mica, garnets, magnetite, and hæmatite; and of these, quartz and hornblende are the most abundant.

According to the way in which these minerals are combined, the gneiss may be divided into several varieties, of which the chief are :—

(1) A very quartzose gneiss, with hornblende or mica. Generally well-laminated. The hornblendic constituent is variable in quantity and sometimes absent, so that we find beds[1] of almost pure quartz. These, it may be remarked, are not reefs, but beds.

(2) Compact hornblendic gneiss. Occurs generally in bands, which behave as dykes, being quite independent of the lamination of the surrounding gneiss. Nevertheless, it is sometimes extremely difficult to make out a definite boundary. The rock seems to pass gradually into the more quartzose and better-laminated gneiss at its sides. It is probable that two sorts of gneiss have been included under this head—the one being truly eruptive, and the other forming part of the main gneissic series.

(3) Quartzo-hornblendic gneiss, with the crystals apparently arranged with their axes parallel to one another. This is composed of small crystals and grains of quartz and hornblende. It forms bands which stand up as conspicuous ridges, usually of no great length. The direction of these bands and of the lamination of the rock is generally east to west.

[1] The term 'bed,' when applied to gneissic rocks in this paper, is used in its most general sense; and must not be understood to imply that these rocks are of sedimentary origin.

(4) Garnetiferous gneiss. Quartz is usually the predominating mineral in this rock; but the presence of garnets and the granular condition of the quartz distinguishes it from the quartzose gneiss. The quartz is in small grains and is of a yellowish colour. The amount of hornblende varies, but is not often very great. Felspar is found in small quantities. Garnets are occasionally very abundant, but usually subordinate to the quartz.

(5) Quartzo-felspathic gneiss. Felspar forms the greater part of the rock. Quartz occurs; but there is very little of any other mineral.

(6) Hæmatite and magnetite gneisses. The hæmatite or magnetite takes the place of the hornblende of an ordinary gneiss; the rock being usually composed of hæmatite (sometimes magnetite) in small crystals or in bands, and grains of quartz. The hæmatite is sometimes converted into yellow ochre, and the rock becomes soft and is easily worked.

(7) Granitoid gneiss. Very rare. About a mile east of the hill marked Kawoo on the Atlas Sheet (5 miles north-north-west of Pattambi) is a small exposure consisting of large felspar crystals (compared with the ordinary felspar of Malabar) and blebs of quartz. On the southern slopes of the high ridge north of Manárkád (Munaur), a true granitoid gneiss occurs, which seems to be intrusive.

Of these chief types of gneiss, Nos. 2, 3, and 7 may be intrusive. The rest belong to the main gneissic series.

Owing to the great extent of country covered by laterite, it is impossible at present to explain exactly the relations of these varieties of gneiss to one another. But some points already made out are worthy of notice.

In the Beypore River between Nilambur and Eddawannah (Eddamunnah) and thence south to Pandikád, the gneiss is almost

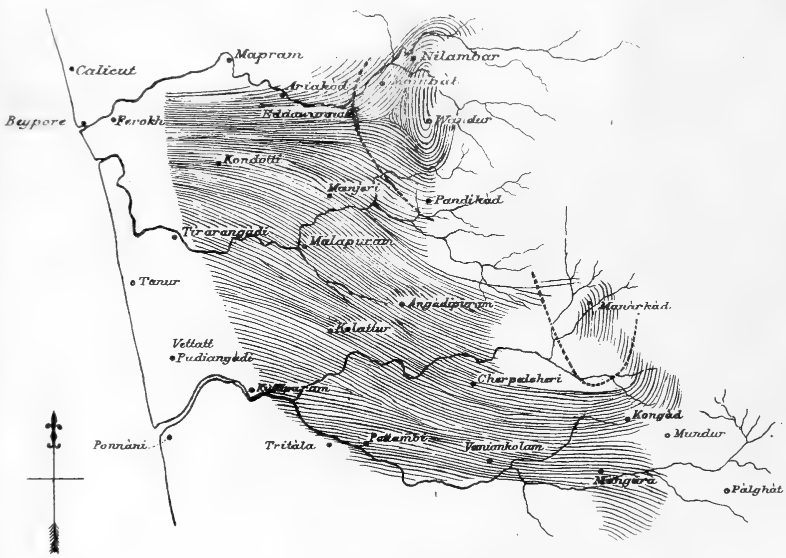

Fig. 4. Foliation of Gneiss.

Boundary of Quartzose Gneiss (roughly)----

Scale 1 in = 16 m.

Plate. II.

always of the very quartzose type, large masses and bands of hornblendic rock, however, being found in it. Another area of similar gneiss is found round Manárkád (Munaur).

On the west of the Nilambur-Pandikád area, the quartzose gneiss is succeeded by garnetiferous quartz gneiss (at Manjéri, Kondotti, Pandalur Hill, &c.) ; and further west still this is followed by felspathic gneiss. The same succession is found to the south of Pandikád.

The Manárkád quartzose gneiss is succeeded on the west, south, and east by felspathic gneiss ; but garnetiferous gneiss is less common than in the north.

Whether the two areas of quartzose gneiss are united is uncertain, for the country between has not been examined. But it is very likely that a band of quartzose gneiss runs along the foot of the Ghâts between Pandikád and Manárkád.

From the way in which the felspathic gneiss seems to dip away from the quartzose gneiss (*e.g.*, in Kalladikód Hill), it is probable that the quartzose gneiss is the lowest bed exposed in the axis of an anticlinal running from Nilambur to Manárkád ; *i.e.*, parallel to the remarkable line of gneissic hills (Urótmala, Pandalur, Pranakód) which rise above the Malabar plateau. If this be so, the gneiss may be divided into three series succeeding one another in the following order :—

(1) Quartzose gneiss.
(2) Garnetiferous quartz gneiss.
(3) Felspathic gneiss.

The anticlinal dies away to the south, and the higher beds curve round the southern end of the quartzose gneiss area. The same seems to take place north-west of Nilambur, but the examination of that part of the country is not complete.

The relation of the foliation of the gneiss to this anticlinal axis, or to the quartzose gneiss areas, is of some interest. It may be seen in the small map (Fig. 4, Pl. II).

The quartzose gneiss itself is almost always laminated nearly

from north to south; but towards the north the direction changes slightly. The foliation of most of the other gneiss is east to west, but it curves round the quartzose masses in a peculiar manner.

The foliation of the gneiss does not always coincide with the banding. Thus, in the hills south of Mungadda (near Pandalur Hill), the bands or beds of gneiss strike nearly north to south (dipping west), while the foliation is 22° S. of E. Similarly near Pattambi (on the Ponnáni River), the railway section shows beds dipping west, and close to the railway these bands are seen to strike north to south; but the lamination is 5° S. of E. Near Cherpalcheri, Watapalam, and other places in the south-eastern part of the area, the banding and lamination seem to agree. The strike is about east to west, but it curves round the southern end of the quartzose gneiss mass. In the north-western part of the area it is not at all improbable that the bedding may be parallel to the axis of the anticlinal described, though the lamination is east to west.

In the case of the higher ridges (Chikmala, north of the Beypore River, and the line of hills comprising Urótmala, Pandalur, &c.), the lamination is parallel to the direction of the ridge.

The same order, which is found among the different varieties of gneiss in proceeding from the most quartzose to the coast, is found also in ascending some of the higher hills. Near Eddawannah the gneiss in the river is of the quartzose type. If we climb the ridge just north of the river, we soon leave the quartzose rock and come to a very hornblendic variety, which reaches up to a height of 700 feet. The upper part of the ridge is composed of garnetiferous gneiss.

Similarly, the lower part of Pranakód Hill near Angádipuram is composed largely of hornblendic gneiss, and the upper part of quartz-hornblende-felspar gneiss of the garnetiferous type.

Quartzose or lowest gneiss.—The typical form of this gneiss has already been described. It usually consists of quartz and hornblende,

Quartz masses and beds.

sometimes of quartz and mica. Sometimes the hornblende is entirely absent, and we find bands

of pure quartz occurring in the gneiss. On the road from Wandur to Nilambur, between the 11th and 12th milestones (which count from Pandikád), what appears like a quartz reef rises through the laterite. Its direction is 5° E. of S. This being the direction of the lamination of the neighbouring gneiss, it is probable that this apparent reef is only a bed.

Shortly before the Wandur-Nilambur and the Eddawannah-Nilambur roads meet, there is, on the east of the former, a low jungly hill, the rock of which is almost pure quartz. Just before reaching Nilambur, there is again another hill (on the west side of the road) with a large band of quartz.

If we go east from Wandur towards the Silent Valley, we again meet with large beds composed of nothing but quartz. They always run in the strike of the gneiss, and are beds, not reefs. Small veins of quartz are very common, but none of large size were met with.

Hornblendic gneiss.

Large masses and runs of hornblendic rock are not uncommon in the quartzose gneiss, especially in what appears to be the upper part of it. Most of the rock near Nilambur is highly quartzose; but what is known as Nilambur Hill is very hornblendic. About 3½ miles north-east of Nilambur, on the Karkur road, is another mass of hornblendic gneiss; and near the banks of the Shaulay-ar of the map (east of the letters *au*) the rock is compact hornblendic gneiss. The hills near Eddawannah are largely composed of similar rock.

These are the most important occurrences of large masses of the compact hornblendic gneiss. But small runs resembling dykes are very common. In the valley of Chatalur, south of the Chikmala ridge, there are four running 15°—50° S. of E. The rock is not precisely the same as that of the large masses; and it is probable that these runs are truly eruptive.

Iron-bearing gneisses.

The hæmatite gneiss is another variety occurring in the midst of the quartzose series. About a mile and a half south-west of Nilambur is a little group of jungly hills, the most southerly of which is partly composed of schistose

hæmatite gneiss. The hæmatite seems to take the place of the hornblende of an ordinary gneiss.

About six miles east-south-east of Wandur, south of the old Sisspara Ghât road, there is another mass of somewhat similar gneiss. The rock is here composed of small grains of quartz and garnet, with narrow bands of hæmatite running through it. The garnets are sometimes partly decomposed to ferric oxide and most likely the hæmatite bands are the final result of this decomposition.

Five miles south of Wandur on the boundary between Porur and Chembréri amsams (just north of the final *m* of Yerramungalum of the map) there are two bands of ferruginous gneiss. The western one, the direction of which is well marked, runs 30° E. of N. It has once been worked, tunnels having been driven into the softer parts of the rock. The other band is still worked by means of shafts and galleries. The rock in both cases consists of small grains of quartz, garnet, and magnetite, with a variable amount of yellow ochre. Where the yellow ochre is abundant, the rock is soft and easily worked.

On the road between Manárkád and Pálghât, in Tachambára (Tutchumparae) amsam, about two miles south-east of Yeddacoorchy of the map, there is more hæmatite gneiss.

Garnetiferous gneiss.—This is more homogeneous than the quartzose gneiss, but bands of more hornblendic rock occur in it. About four miles north of Angádipuram, the hill marked Turitiancoon is composed of magnetite gneiss, similar to that found in Porur amsam. This seems to be in the garnetiferous, and not the quartzose, series.

Quartzo-felspathic gneiss.—This is best developed in the south of the district. Typically it contains very little hornblende, but hornblendic and micaceous bands are found in it in many places. Occasionally garnets occur in this gneiss.

Lenticular masses of quartz are sometimes found, *e.g.*, at Cherpalcheri, and about two miles from Natgalli[1] on the Manárkád road. At Natgalli is another mass of quartz which is highly ferruginous and has at one time been worked for iron.

[1] Natgalli lies about half way between Angádipuram and Manárkád.

The *quartzo-hornblendic gneiss* with the crystals arranged with their axes parallel to one another can hardly be said to belong to any one of the three great groups, for it may be found anywhere. The best examples are found to the north of Manjéri and to the north of Pandikád.

Intrusive rocks.

All the intrusive rocks of this area being pre-lateritic, it will be convenient to describe them next.

Some of the highly hornblendic rocks already mentioned are probably eruptive, and this may be the case also with the bands of quartzo-hornblendic gneiss north of Manjéri and Pandikád. But besides these there are some undoubted dykes which are of considerable length, though much concealed by laterite.

The most remarkable is one which forms a conspicuous ridge just south of Pandalur Hill. It runs to the south-east, crossing the Angádipuram-Manárkád road about half a mile east of Perintalmanna. Near Cherpalcheri it is again well seen forming a high ridge which touches the west side of the high conical hill two miles south-west of the village. It still continues its south-easterly course and is found about two miles north-west of Watapalam. This dyke is composed of white felspar, hornblende, and magnetite. The magnetite is very abundant, and with the hornblende forms little nests in the felspar. At Angádipuram the sides of the dyke are compact, and the middle is crystalline as just described. This is also the case in other places, the borders of the dyke being sometimes almost felsitic in structure. A small dyke of this felsitic rock is found on the road from Manjéri to Malapuram, about two miles from Manjéri. This is not exactly in the line of the big dyke, so that perhaps it is only an offshoot from it.

The other dykes consist of a very different rock. They are composed of felspar and augite; the augite forming ophitic masses. On a line running just east of Manjéri, in a direction from 67° N. of W. to 67° S. of E., several exposures of trap are seen. The most northerly is about a mile east of Wakalur on the Beypore River. The direction of the dyke here, however, is 15° S. of E., so that if it is con-

nected with the main dyke at all, it must be only as an offshoot. At Manjéri, east of the bungalow, there are several parallel dykes forming well-marked ridges. They are found also a little further north. The direction is very variable, but the average must be about that of the line of exposures. On the road between Pattambi and Cherpalcheri, near the 6th milestone (numbered from Cherpalcheri), this dyke re-appears. About three miles further south it was again observed. All these exposures lie in one straight line, and except at Wakalur, the direction of the exposed dyke is about the same as that of the straight line. There can be no doubt that they belong to one great dyke or system of parallel dykes.

The next large dyke is exposed on the flanks of Wallaiur (Wulliatoor) Hill; on the Kondotti-Ariakód road in the valley north of Kondotti Hill; on the Manjéri-Malapuram road, two miles from Malapuram; and again about a quarter of a mile east of Perintalmanna bungalow. The general direction is 35° S. of E.

The third dyke is exposed about a mile south of the point marked Clary on the map (two miles west of Kottakal); a mile west of Wakatoor on the road from Kuttipuram (Kollypuram) to Kolattur (Collatore); and two miles south-east of Tritála. The general direction is 52° S. of E.

Finally, south of Anangamala, near Panamunnah of the map, is a double dyke of considerable size running 43° S. of E. This has not been seen in other parts of the district.

There are, therefore, four chief dykes of this type of rock, *viz.*:—

Manjéri	dyke	67° S. of E.
Wallaiur	"	35° S. of E.
Tritála	"	52° S. of E.
Anangamala	"	43° S. of E.

Besides these four large augitic dykes there is a fifth of considerable size which crosses the Pandikád-Angádipuram road just south of the Pandikád River. Its direction is 30° S. of E.

There is a third kind of intrusive rock found in Malabar, of which I have seen only one example. This is found on the southern slope of the ridge running easterly from Purrumulla Peak north of Manár-

kád. In the side of the cliffs of this ridge a sheet of felsite of considerable thickness is seen to be intruded into the gneiss. The dip of the sheet is low and to the west.

Laterite.

There are two chief varieties of laterite found in South Malabar, which may be named the vesicular and the pellety[1] varieties.

The *vesicular laterite* is a ferruginous hardened clay, penetrated by numerous vermicular, branching, and anastomosing tubes, which are usually about half an inch or less in diameter. In the parts that have not been exposed to the air, these tubes are filled with a white or yellow clay containing a much smaller percentage of iron than the walls of the tubes, and a much larger percentage of potash. The deeper we dig into the laterite and the less affected it is by the weather, the fainter becomes the distinction between the walls of the tubes and their contents, till at last it may disappear altogether, and what is laterite above is simply a clay below. This shows, if it were necessary, that the peculiar structure of laterite is due to a kind of concretionary action—the iron tending to segregate in the form of tubes, from which, when exposed, the clayey, non-ferruginous parts are washed out. The exposed laterite has therefore a higher percentage of iron than the clay from which it was formed. The passage downward from laterite with much iron to an ordinary clay is seen in the railway cutting a short distance south of Tirur Station. The surface of the hill through which this cutting is made is of typical laterite, while the deeper parts of the section show only a somewhat sandy, irregularly laminated clay.

This form of laterite is easily dissolved by water wherever there is a surface of contact between the water and the air. When the side of a well or pond is of laterite, irregular little caverns are hollowed out at the surface of the water. Usually long vertical tubes of considerable width are formed at the same time. They are

[1] This is generally distinguished from the "pisolitic laterite" of the east coast by the much smaller amount of cementing material present. The vesicular laterite is nearly the same on both coasts.

no doubt due to percolation of water from above, but they are never found except when the laterite is in contact with water below.

The vesicular laterite sometimes, in spite of its porous character, puts on a massive appearance and may be jointed, the joints being vertical and running in two sets at right angles to each other. Usually these joints do not appear except at the edge of a cliff; but sometimes, as on the hills north of Kadananjéri[1] (half way between Calicut and Kondotti), they are found on a level surface well away from the edge of the cap.

At other times the laterite is laminated, usually parallel to the lamination of the gneiss of the neighbourhood; and sometimes it is pierced by quartz laminæ and veins rising from the rock below. It not uncommonly includes angular blocks of gneiss or, still more often, of quartz; and occasionally it contains well-rounded pebbles. The blocks of gneiss may be of almost any size, from the largest to the smallest.

The *pellety laterite* is usually much more solid than the other, and consists of small irregular nodular-looking pellets of red oxide of iron cemented together by similar material. There are no vermicular tubes, and the rock has a higher percentage of iron than the unexposed parts of the vesicular variety. Probably the percentage is nearly the same as that of the tube-walls of the other form.

The mode of formation of this variety is not difficult to follow, and in many places the process may be seen going on. The exposed parts of the vesicular variety, after the contents of the tubes have been washed out, slowly break up. The tube-walls break into little sub-angular irregular pieces. Very often where a large level surface of laterite is exposed, it is found to be covered with these little masses; and these little masses are precisely like the pellets forming the main part of the pellety laterite. They are washed away by the rain or rivers and deposited at a lower level, where they are re-cemented together. It is chiefly on old river terraces that this form of laterite is found.

[1] Not marked on map. Lies about a mile north-west of Chelimbur.

Fig. 5. Section through Pandikàd.

Fig. 6.

Fig. 7.

Fig. 8. Section through Kuttipàli Ridge.

Vertical Scale 1 in about 200 ft.

At Pandikád (8 miles east of Manjéri) the relation between the two varieties is well seen. The village lies in a valley, to the east of which is a ridge about 240 feet higher, capped by vesicular laterite, in which are a few small angular fragments of gneiss. The side of the ridge is of gneiss and at the foot is pellety laterite full of angular blocks of gneiss (Fig. 5, Pl. III).

The blocks of gneiss are by far more numerous just at the foot of the hill than at some distance off. It seems clear that the lower laterite has been formed by the washing down of the pellets from above; and that at the same time blocks of gneiss have fallen with them from the side of the hill.

These are the two chief varieties of laterite; but, though the general distinction between them is clear, there are many areas of laterite in which the two are mixed. When the pellets of laterite, washed down from some higher place, become mixed with clay, a new concretionary action is set up and the pellets may be partially or entirely obliterated. Or on a surface of the vesicular laterite a sort of vein of the pellety variety may be seen running through it. This occurs, for example, on the hills north of Kadananjéri. No doubt a cleft or joint was first formed (and in the Kadananjéri laterite the joints are particularly well marked) and the pellets derived from the neighbouring rock washed into it.

Again, the upper part of a bed of laterite may be pellety, while the lower is vesicular.

Distribution of Laterite.

In accordance with the physical features of the country, the area under consideration may be divided into four regions already described, *viz.*—

(1) The coastal region.
(2) The undulating region.
(3) The gorge region.
(4) The plain at the foot of the Ghâts.

In the first, there is very little laterite visible at the surface; nothing but a few low hills and rocks.

In the second (Fig. 1), almost the whole surface is covered with laterite, both the hills and the valleys. As some of these hills, including the western cliff, rise to a height of 150 feet, and are covered from base to summit, it appears as if the laterite were at least 150 feet thick. But this is not by any means always the case.

The hill forming the edge of the great plateau, about four miles east-south-east of Tanur, is covered with laterite from its foot to its highest point. But its top is a very distinct *cap* with a vertical scarp, and it is from the *foot* of the cap that the ground begins to slope down to the sea, so that the laterite on the slope does not seem to be continuous with that of the summit. The section exposed in a small raingully on the side of the hill explains the matter (Figs. 6 and 7, Pl. III).

At the bottom of the gully, gneiss appears at two points (a, b, Fig. 6). Remembering that laterite, except when it occurs as a reconsolidated talus, almost always lies nearly level, the section of the hill must be as in Fig. 7. The thickness of laterite is inconsiderable, and the covering of the side of the hill is the remains of a terrace of laterite or is simply talus fallen from above.

In other similar cases in this region, a close examination generally reveals a narrow belt of gneiss running round the hill and separating the true cap from the laterite of the valley. Further inland the zone of gneiss becomes better defined, and the laterite is divided into two distinct portions, one capping the hills and the other flooring the valleys. This is very well seen on the road from Tirur Station to Malapuram (near the 11th milestone from Malapuram) on the east side of the ridge east of Ponmundum of the map (Fig. 8, Pl. III).

If the valley be narrow, there may be no laterite deposited in it, the whole valley may be gneissic and the laterite forms only a cap to the hills. This is the case in the gorge region. But in this region there are some broad valleys, and it is at the bottom of these that the gorge is cut (Fig. 2). The broad valley is then covered with laterite and the gorge cuts through it into the gneiss; and so a river-terrace is formed.

Sometimes the upper broad part of the valley is very broad indeed; and instead of *one* gorge, a number of channels of various depths are cut in its floor. At last the original floor of the valley is so much cut up as to leave only a number of low hills capped with laterite, quite isolated from each other. The caps are the remains of the laterite that once covered the bottom of the broad valley. In the section from Pandalur Hill to Kurnád Hill (Section II, Pl. VIII) one of these broad valleys is shown. The dotted line shows the original surface of the valley, which is now cut up by numerous rivers and streams.

In this region (gorge region) several high gneissic hills rise far above the highest laterite. They have already been alluded to.

The plain near the foot of the Ghâts is to a great extent covered with laterite; but the covering is thin and incomplete. The valleys are cut down into the gneiss and many low gneissic hills rise above the level of the laterite.

From the sections and descriptions just given, it is clear that the laterite may be divided into three groups, *viz.*:—

(1) Plateau laterite,
(2) Terrace laterite,
(3) Valley laterite,

and as the plateau must be older than the valleys cut in it, it appears that this is also the order of age. But the plateau near the coast being newer than the higher part, some of the valleys may be older than some parts of the plateau.

As we have already seen (Fig. 2) that the terraces (including the isolated hills of Section II) are the remains of the floors of old river valleys, so is the terrace laterite an older valley laterite.

The plateau laterite has been formed on a plain of marine denudation, and the other two in river valleys.

Plateau laterite.—This is almost always of the vesicular type. Occasionally it includes angular quartz and gneiss masses, usually of small size. They have already been mentioned as occurring at Pandikád, and they also occur on the high conical hill two miles south-west of Cherpalcheri, and in many other places. Sometimes, as in the

small high caps close to Perintalmanna (near Angádipuram), this laterite is laminated, and the laminæ of the gneiss below project into it. On the hills north of Kadananjéri the plateau, which is there low, has two sets of joints at right angles to each other. Near Mambram (close to Tirurangádi) the laterite is obscurely laminated, the direction of lamination being nearly east to west, which is also that of the foliation of the nearest gneiss.

The extent of ground occupied by plateau laterite is considerable. It covers almost the whole of what is left of the plain of marine denudation, and is found nowhere else. All the laterite below the level of the plain must be referred to one of the other groups.

But the plain of marine denudation has been very much cut up by denudation and only remnants of it, and therefore of the plateau laterite, are left, and these must now be pointed out.

Towards the coast (see Fig. 1) there is not always a sharp line between the plateau laterite and that of the valleys, and it is enough for the present that the higher parts of the ridges are covered by the former and the long slopes by the latter.

But further inland the distinction is well marked. To the north of Malapuram a ridge capped by the highest laterite runs from north to south between Urótmala and Pandalur Hill. The "Cholera Hill" near the barracks is an outlying part of this ridge. On the other side of the river, to the south-east, the high flat hills of Kuddoocotah and Perindatry are also remains of the plateau. The line is continued by the hills south of Kurkadum[1] and the high hills south of Mungadda, and finally by the two little caps on the high summit close to Perintalmanna. All these are capped by laterite, and all are of nearly the same height. Further to the south-east the line is not continued, but descending is merged in the laterite of the plain at the foot of the Ghâts.

South of the river flowing from Angádipuram to Malapuram, there is another line of high laterite-capped hills. It is much more conti-

[1] These and other names are used to refer to the points marked on the Atlas Sheets. The "villages" themselves are scattered and cover wide areas.

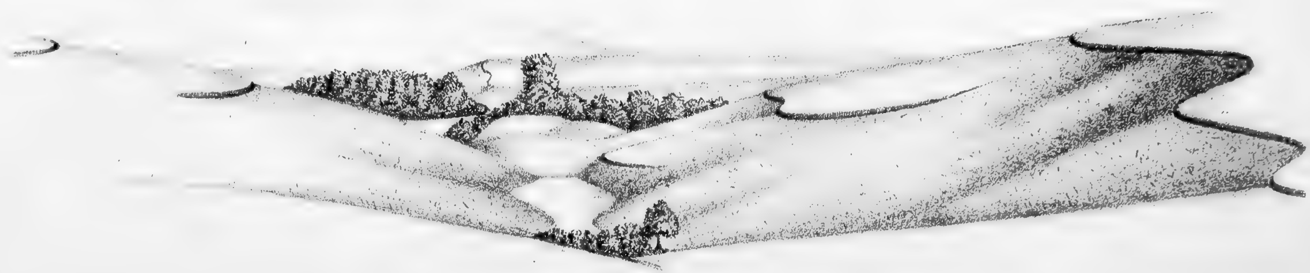

Fig. 9. Laterite Terraces S. E. of Kottakal.

(looking north)

Plate. IV.

nuous than the first, and runs from Puttur (Poothur), near Kottakal, to Umbelum (east-north-east of Kolattur), with only one break. This break is by no means so complete as it appears on the Atlas Sheet, but it is fairly distinct. The line is continued to the south-east by Ananghât Hill, and some of the hills south of Cherpalcheri, and there it ends.

All the hills belonging to these two lines are of approximately the same height; and except that of the hill near Mooloorah (between Pattambi and Cherpalcheri), there is no other laterite so high. There can be no doubt that they are the remains of what was formerly a broad plateau. This may almost be seen on the Atlas Sheet, and in the field it is still more apparent.

South of the second line there are a few more high caps at a rather lower level. They lie between the Tudhakal and Ponnáni Rivers. The chief are the hill marked Kawoo (5 miles north-north-west of Pattambi) and the hill east-north-east of this; the ridge about 2 miles south of Kawoo; Ramgiri Fort Hill (near Kulladypetta of map), &c.

South of the Ponnáni River the remains of the plateau are very numerous near Tritála. The height here is about 350 feet. East of Tritála, in the State of Cochin, the country is mostly gneissic and hilly, and there are no remains of the plateau near the river.

South-west from Pandalur Hill and Malapuram the plateau is not nearly so broken up, and almost all the laterite-topped ridges belong to it. There are no caps belonging to the terrace laterite such as are shown in Section II, Pl. VIII.

As we approach the Ponnáni River, or the coast, the height of the ridges becomes gradually less. It is about 250 feet at Kuttipuram (=Kollypuram, on the north bank of the Ponnáni River, about 8 miles below Tritála).

To the north again it is the same. Most of the caps belong to the plateau laterite, and their height gradually decreases towards the Beypore River, where it is 200 to 250 feet.

Eastward, the plateau, represented by the hills of Manjéri and

Pandikád, slopes downwards. North-east the slope is still greater. The Pyenád Hills, east and north-east of Manjéri, rise in many places above the laterite, and the level of the laterite is lower on the north side of these hills than on the south (see Section III, Pl. VIII). But the supposed remains of the plateau on the north are very scanty, and it is possible that they belong to the next group. Most of the laterite between Pandikád and Nilambur belongs to the valley group.

South-east of Pandalur there are no caps; but the level of the ground is high (350 feet), and it is partly covered with laterite, much of which probably belongs to the plateau, though some may belong to the terrace and valley groups.

Terrace laterite.—This, unlike the plateau laterite, is generally of the pellety variety, as, indeed, might be expected when we remember that it is mainly a river or rainwash deposit. But a certain amount of the vesicular form is found on the terraces; and this has no doubt been formed partly by the decomposition of the gneiss of the terrace floors, and partly by the lateritisation of river clays.

The finest terraces in South Malabar are seen near Malapuram, and on the old road from Tirurangádi through Venkatakotta to Angádipuram.

The small stream valleys are also often terraced. There is a very good example about 3 miles south-east of Kottakal bazar (Venketakota of map). The terraces, in correspondence with the size of the stream, are small, but well marked (Fig. 9, Pl. IV). There are three terraces on the right (east) side of the valley, and two on the left.

There are several other very fine examples of terraces near this one. About a mile west of it there is a spur running from north to south. The valley is filled with laterite, and in ascending the spur we pass first over gneiss, then over a terrace of laterite, and at last reach the cap (Fig. 10, Pl. V).

The slope between the cap and the terrace is, in the line of section of Fig. 10, covered very thinly by reconsolidated laterite. But a little to the east the slope is gneissic.

On the opposite (*i.e.*, west) side of the stream, which flows from

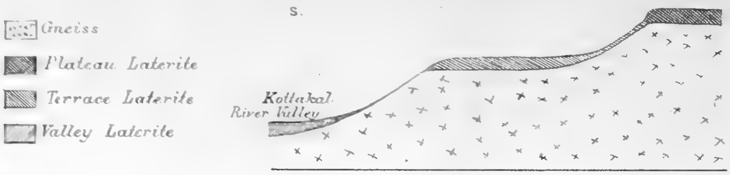

Fig. 10. Section of the S.W. spur of the hills S.E. of Kottakal.
Vertical Scale 1 in — about 500 ft.

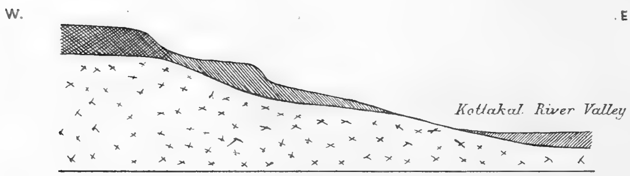

Fig. 11. Section through ridge S.W. of Kottakal.
(near Cullamungalum of map)
Vertical Scale 1 in = roughly 500 ft.

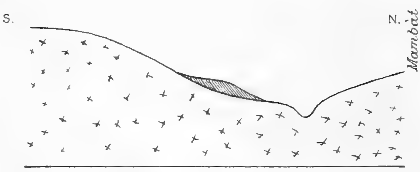

Fig. 12. Section through Mambàt.

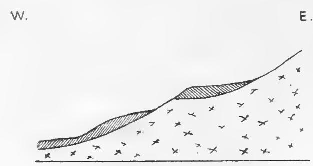

Fig. 13. Section near Kongàd.

Fig. 14. Section through hill E. of Kongàd.

Plate. V.

south to north by the side of this spur (and which passes by Kottakal), there is again a cap, a terrace, and a valley-flooring of laterite (Fig. 11, Pl. V).

Three other examples, on a still smaller scale, may be given.

The first is near Mambát, about 5 miles below Nilambur on the Beypore River. The road from the village south-west descends on gneiss, crosses a stream, and ascends on the other side. In the ascent it passes over a little terrace of laterite (Fig. 12, Pl. V).

The next two are near Kongád (about 11 miles from Pálghát on the old road to Calicut). Near the 14th milestone the road as we go eastward rises from a paddy-flat covered with laterite to a gneiss bank. Still rising it passes over a laterite terrace, and again reaches gneiss (Fig. 13, Pl. V).

Close to Kongád the road crosses a low hill round which, at a height of some 20 feet above the paddy-flats, is a ring of laterite. The top of the hill is of gneiss (Fig. 14, Pl. V).

Valley laterite.—This occurs in all the broader valleys and even in those of many very small streams. In some places, as in the neighbourhood of Manjéri and near Wandur, it forms extensive spreads. Often the channels of the streams cut through it and reach the gneiss below, so that the laterite is really on a terrace raised a very little above the stream. But it is convenient to separate this from the laterite of the higher and older terraces.

In the laterite of the valleys there is often a most complete mixture of the two varieties, pellety and vesicular. It is hard to say which predominates.

In some places, *e.g.*, near Kolattur, Ariakód, and Shoranur, the valley laterite passes down into the gneiss below as if derived from its decomposition.

In a new cutting at the side of the road from Shoranur Station to Vaniamkolam, the passage downwards is well seen. The gneiss is distinctly laminated, and the less easily decomposed laminæ rise up into the laterite sometimes to a height of 2 or 3 feet. The other laminæ are converted into laterite to a corresponding depth.

At Kolattur there are cases where the lateritisation of the gneiss does not take place along its laminæ, but in a spheroidal fashion (Fig. 15). The gneiss is more compact than at Shoranur, and the spaces between the spheroids are full of laterite, the spheroids remaining in their original positions. The layers of gneiss that are beginning to scale off are partially lateritised.

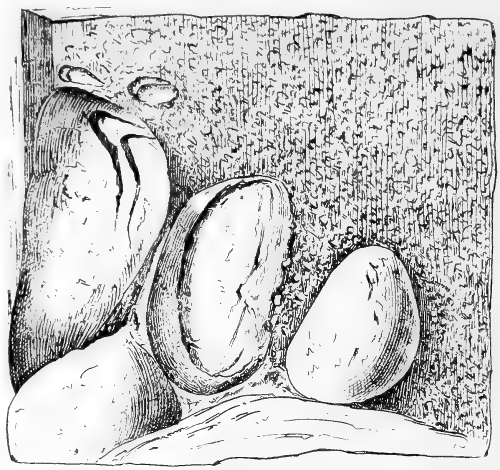

Fig. 15. Spheroidal lateritisation of gneiss.

Near the hill of Turitiancoon, about 5 miles north of Angádipuram, is a small plain, the surface of which is composed of alternate bands of laterite and gneiss. The bands run in the same direction as the bedding and lamination of the gneiss; and the more easily lateritised bands have been converted into laterite while the others are unaffected.

This is not uncommon, and a precisely similar example may be seen about a mile north-west of Parli Station.

These observations all go to prove that some of the valley laterite has been formed by decomposition *in situ* of the gneiss. But there is quite as good proof that some of it is of fluviatile origin, and its distribution seems to show that this is the case with the greater part.

A well-marked long band of laterite follows the course of the Ponnáni River from near Pálghát to Pattambi. It is bounded to north and south by gneiss. A section through Mangara (Muncurray) shows the relation of the laterite to the river (Fig. 16, Pl. VI). It

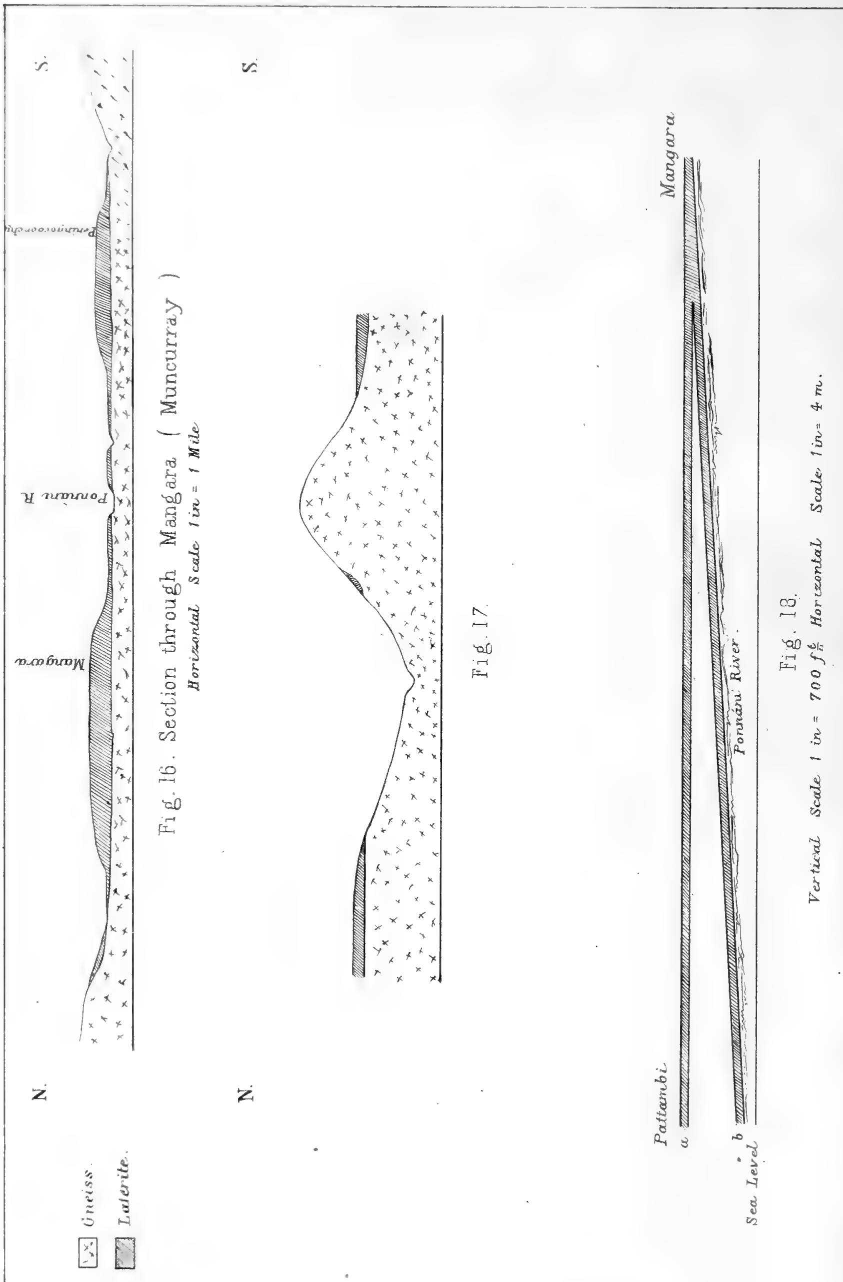

Fig. 16. Section through Mangara (Muncurray)
Horizontal Scale 1 in = 1 Mile

Fig. 17.

Fig. 18.
Vertical Scale 1 in = 700 ft. Horizontal Scale 1 in = 4 m.

fills a shallow valley between two low gneiss ridges, and the actual channel of the river is cut down to the gneiss below.

At the northern border and also at the southern border well-rounded pebbles of quartz are abundant in this laterite, which is more or less pellety.

The band is clearly a river deposit. Near Watapalam, on the north side of the gneiss ridge is another band of laterite, which is, curiously enough, on the same level as the Ponnáni laterite. Fig. 17, Pl. VI, is a section from north to south across the ridge.

The river north of the ridge runs from east to west along its foot and then turns sharply south and flows through a narrow gorge into the Ponnáni River. But the main valley north of the gneiss ridge is continued in a north-westerly direction till it opens into the valley of the Tudhakal River. It is nearly certain that the northern river formerly ran in this valley and was then a tributary of the Tudhakal River, and that the gorge is of late date.

The height of the Ponnáni laterite at Mangara and Watapalam is about 250 to 280 feet. Further down the river a few caps are found at this height, and they were probably once continuous. As the river descends, the height of these caps above the bed increases, for their height above the *sea* remains the same. But there is a lower laterite, some 15 feet above the river which slopes down to the sea at the same angle as the river bed, and hence is everywhere at the same height above the river. Near Mangara, which is about 280 feet *above the sea* and 15 feet *above the river*, there is only one laterite level. The lower sheet of laterite, which has presumably been formed by the Ponnáni River from the higher sheet, starts from this point. This is shown diagrammatically in Fig. 18, Pl. VI.

a is the sheet of laterite, 280 feet above the sea. At Mangara its height above the river is about 15 feet, and at Pattambi about 200 feet. *b* is the laterite which follows the slope of the river at a uniform height of 15 feet above it. The two bands unite near Mangara.

About 3 miles east of Pandikád is a spread of valley laterite, or

rather a low terrace laterite, full of rounded quartz pebbles. So that here again is evidence of a fluviatile origin.

It is hardly necessary to describe any more areas of valley laterite. In most cases the valleys are much better defined than the Ponnáni Valley, and the deposits are clearly fluviatile. There is a very broad spread of laterite around Wandur, the origin of which is not quite clear, but it is probably valley laterite. Other spreads are found near Manjéri, between Manjéri and Eddawannah, &c.

Laterite not belonging to any of the three groups.—A few exceptional cases remain to be discussed.

Near the Ghâts several iron mines are worked and still more were in operation some years ago. Some were visited by Dr. Buchanan[1] when he was staying at Angádipuram. He states that the ore is obtained from the laterite. It was so, perhaps, in some of the mines, but most have been worked in gneiss. Those nearest to Angádipuram, however, in Mangada (Mungadda) amsam, do not pass down into the gneiss. They have not been worked for a long time, but very possibly they were the mines examined by Dr. Buchanan.

In the amsams of Porur[2] (Ernád Taluk), Nemini,[3] and Arakkaparamba[4] (Walluvanád Taluk), the mines have been worked in gneiss. The iron ore, where exposed to the air, becomes converted into laterite. At an old abandoned mine in Porur, there were veins of laterite in the gneiss, which must at one time have been veins of iron ore. In Arakkaparamba there is a sort of neck of laterite (lateritised iron ore) on the top of a hill, and the mines have been dug down through this to the unaltered iron ore below.

Under this heading must also be included taluses of laterite covering the slopes of laterite-capped hills. It is impossible to draw a hard-and-fast line between this form and the valley and terrace

[1] Journey through Mysore, Canara, and Malabar. Madras reprint, 1870. Vol. II, p. 113.

[2] 4 miles north of Pandikád.

[3] North-east slopes of Pandalur Hill.

[4] North-east slopes of Pranakód Hill.

laterites, though as a rule it happens in this area that the distinction is fairly well marked. The terrace and valley laterites lie nearly flat, while the talus laterite covers very steep slopes.

In Fig. 10 the laterite covering the slope between the plateau laterite and the terrace laterite is clearly talus fallen from the former. In Figs. 5, 8, &c., it will be seen that the laterite runs up the sides of the hills above the general level of the valley-floors. It is here, no doubt, mixed with talus from above.

The most important taluses are found on the south side of the high ridge east of Poothur of the map. The height of this ridge above the valley to the south is about 300 feet, and the whole slope is covered by a sheet of laterite. The western termination of this ridge is also partly covered by talus, but the gneiss of the hill appears in many places.

Origin of Laterite in Malabar.[1]

As we have seen, there are two chief varieties of laterite in Malabar. The mode of origin of the pellety form has already been described. The other is the result of concretionary action taking place in a ferruginous clay, and it now remains to determine how far this clay is of detrital origin, and how far it has been formed by the alteration *in situ* of gneiss. Evidence has already been given that sometimes laterite has been formed by the one process and sometimes by the other, but a few critical sections have still to be described.

A few hundred yards south of Ferokh (Ferokkabad) Railway Station there is a cutting through a low laterite hill. From its position, this laterite appears to have belonged to a terrace on the seaward side of the western edge of the plateau. It is now quite cut off from the plateau and is too low ever to have belonged to the plateau itself.

The upper part of the face of the cutting (Fig. 19, Pl. VII) is laterite with a rather low percentage of iron. It is in some places distinctly bedded, or at least laminated horizontally. Below this is a thin

[1] For remarks on the origin of laterite in other areas and a history of previous views on the subject, see Appendix.

layer of very hard chocolate-coloured rock containing grains of quartz. This is about 9 inches thick. In some places (*a*. Fig. 19) there are several layers of this rock in the laterite, and these unite to the south to form one thin bed. The hard band is therefore to a certain extent interbedded with the laterite. To the north of the figure the chocolate band again rises into the section. Further north it breaks up into several smaller bands, and these thin out gradually and disappear, but still more to the north the band again comes into existence.

Below the thin hard bed is a very soft sandy clay mottled red and white, but weathering to a dull black. Where the chocolate band dies out, the clay and the laterite come into contact with each other and the clay becomes converted into laterite, so that the distinction between the two disappears. When the band comes in again, the upper and lower parts of the section are again distinct as in the figure.

In the section close to the station the two rocks are distinct without any intervening hard band (Fig. 20, Pl. VII).

In the first section, from the way in which the laterite and the chocolate-coloured rock are interbedded, it is clear that both are detrital. But the lower sandy clay shows no trace of bedding, and is just like the sandy clay formed by the decomposition of felspathic gneiss in other parts of Malabar. Yet, when it is not protected by the hard band above it, it becomes laterite and is undistinguishable from the detrital laterite of the upper part of the section.

In this case therefore we find a bed of laterite, the upper part of which is detrital and the lower probably formed by decomposition in place of the rock below.

From the mode of distribution of the laterite of the river terraces and valleys, it seems that this laterite must be mainly of fluviatile or pluvial origin. There are, however, many places where it has been formed by decomposition *in situ* of the rock below.

This is especially the case with the valley laterite. Between Cherpalcheri and Angádipuram, about a mile north of Tudhakal ferry,

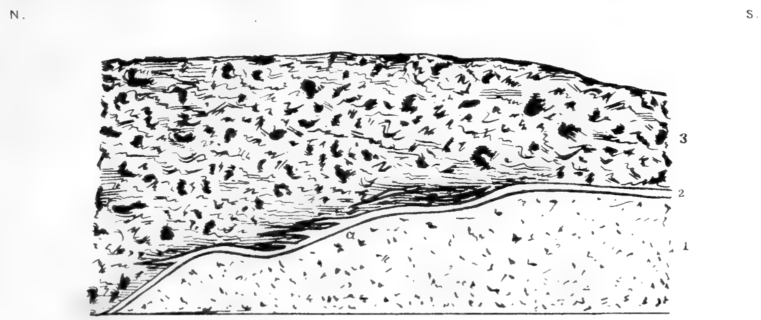

Fig. 19. Railway cutting near Ferokh.

1. Red & white mottled Sandy clay

2. Chocolate band

3. Laterite

Height of Section about 20 ft

Fig. 20. Section at Ferokh Station.

a. Sandy clay

b. Laterite

c. Lateritic earth.

there is laterite full of large quartz grains. It belongs to a low terrace, and at first sight might be thought to be detrital. But the gneiss near is found to be full of precisely similar grains of quartz. Both this form of laterite and this form of gneiss are very uncommon in South Malabar; and as they occur together, it may fairly be inferred that the laterite was formed from the gneiss by decomposition *in situ*. Certainly the materials of this laterite cannot have been carried far before consolidation.[1]

The origin of the plateau laterite is much more difficult to determine than that of the terrace and valley laterite. The only evidence in favour of a detrital origin is the occasional occurrence of blocks of gneiss in it, and the fact that in the central part of the plateau there is a sharp line between the laterite and the gneiss. The blocks of gneiss, however, are always angular, and in the western part of the plateau the laterite passes down into the gneiss. The plateau laterite is sometimes laminated in the same direction as the nearest visible gneiss, and the laminæ of the gneiss sometimes project into the lower part of the laterite.

Near Kuttipáli (about 11½ miles from Malapuram on the road to Tirur Station) the well sections show that below the laterite there is a sandy yellow clay containing blocks of decomposing gneiss apparently *in situ*. This clay is found below the laterite both on the hills and in the valleys, and where there is no laterite there is none of this clay. At Tirur Station the railway section shows that the laterite is only the upper lateritised part of this clay. The section near Ferokh also shows that this clay, when exposed to the action of percolating water, becomes laterite. The included blocks of gneiss at Kuttipáli seem to prove that the clay is simply decomposed gneiss; and hence the laterite is formed by the action of the weather on the decomposing surface of gneiss. Whether this is so for the whole plateau or not, it certainly appears to be the case here.

There have been abundant proofs given that laterite is sometimes

[1] For other examples of the formation of valley laterite by decomposition *in situ*, see pp. 25 and 26.

formed by decomposition in place of the gneiss below; and the high percentage of iron in it must now be accounted for.

The gneiss of South Malabar is mostly a very fine-grained loosely-built rock composed of quartz, felspar, hornblende or mica, and garnets. The rock is very easily decomposed and friable, and in the western parts of the district (where the laterite is thickest) becomes converted into a clay with specks of iron oxide replacing the hornblende and garnets. If it is now exposed to the weather, the iron segregates, and where it collects, hardens and compacts the clay together. The rest of the clay, where there is no iron, is loose and easily washed away. When these non-ferruginous parts are carried off, the surface necessarily has a higher percentage of iron than before. This process goes on till the gneiss is covered by a cap of laterite. When the cap is old, it becomes laterite throughout its whole thickness and probably protects the gneiss from further decomposition. There is then a tolerably sharp line between the laterite and the gneiss, as we find in the higher and older parts of the plateau. But when the process has gone on but a short time, only the upper surface of the decomposed part of the gneiss is converted into laterite. There is then a passage from laterite into a clay below, and from this clay to the gneiss. This is what we find in the newer parts of the plateau, near the coast, as at Kuttipáli.

The plateau laterite, it must therefore be concluded, has been formed by the decomposition of the gneiss. That the material so formed was partly re-arranged by rain, &c., can hardly be doubted; but, speaking generally, the rock was found *in situ*. It is hard to see how detrital matter could be deposited in a thin and regular layer, such as the plateau laterite, on a plain of marine denudation; but we may easily imagine that as the surface rose above the sea it would become decomposed and finally lateritised.

Comparing the descriptions of the three great groups of laterite with the modes of origin assigned to them here, we may conclude that the vesicular laterite is generally formed by decomposition *in situ*,

nd the pellety laterite by fluviatile or pluvial action. Our results may then be tabulated thus ;—

Group.	Nature of the Laterite.	Origin.
Plateau laterite.	Vesicular.	Non-detrital.
Terrace ,,	Pellety.	Detrital.
Valley ,,	Partly vesicular, partly pellety.	Partly non-detrital, partly detrital.

Speaking generally, laterite in Malabar has been formed by the decomposition of gneiss and the partial re-arrangement by the mechanical action of water of the resulting materials. In other words, *it is really a soil.*

In many cases most of the oxide of iron which is collected together by concretionary action remains *in situ*, while the clay is washed away. In other cases, however, the oxide of iron is washed away with the clay and forms laterite in some other place. However it has been formed, the laterite is always liable to be broken up and re-deposited elsewhere in the form of pellety laterite.

Recent Deposits.

The deposits in South Malabar of later origin than the laterite are not of much importance and need only be alluded to.

Lieutenant Newbold[1] describes the bank of the Beypore River near Beypore as made up of the following series of beds :—

	Ft.
Sandy alluvial soil	4
Loose sandstone with beds of ochreous earth	10
Gritty sandstone passing into gritty laterite, the lower part variegated with red and yellow bands	20
Carboniferous stratum, a few inches to	5

It has been suggested (District Manual, p. 21) that these are the representatives of the Warkilli beds. But there is no proof that this is the case.

My own stay at Beypore was short, and I did not find the carboniferous stratum mentioned by Lieutenant Newbold. The banks of the river are partly marine and partly fluviatile deposits, and irregular seams of lignite may be expected to occur in these.

[1] Madras Journal of Literature and Science, Vol. XI, p. 239 *et. seq.*

In boring in the bed of the Kallai River at Calicut (for foundations for a bridge) a bed of oily shale was found, resembling (so far as can be judged from dried specimens) the mud of the mud-banks at Alleppy and Narrakal. There is a mud-bank at Calicut similar to these, but much smaller, and it is probably the seaward outcrop of a bed similar to that found in the boring. This bed thins out to north and south, as is shown by the other borings.

Fishbones and shells have also been found in some borings made in this river, but I have been unable to get any specimens. The beds are probably marine and estuarine in origin.

The banks of the Ponnáni River near Kuttipuram are loamy, and close to the top of the bank collections of shells were found, and also a piece of semi-fossil resin. It is very likely, however, that these shells were placed there by human agency, and in fact pieces of pottery were found with them. The pottery was of recent make.

In other places marine and estuarine shells are found in great numbers. Near Kuttipáli at a height of 250 feet above the sea, several were found scattered on the surface.

On the sides of the hill, about a mile east of Ferokh, very large numbers of bivalve shells are found imbedded in a loose pellety laterite. As the laterite is found on the side of the hill in a valley cut through the plateau, it is evidently newer than even this, the western, part of the plateau laterite. The shells are estuarine and have no doubt served as food (for most of them belong to one species), and it is probable that there is here a sort of "Kjokken-mödding." Even now, heaps of perfectly fresh shells are constantly found near the huts, and a villager informed me that they were brought from the river at Mammali (near Ferokh). The shells in the laterite are sub-fossil, with all the pearly layer worn away and must be of considerable age. They are found in the sides of the little gullies and footpaths. They serve to show that laterite has been forming here since man came to this part of the country.

In many other places along the banks of the Beypore River,

similar collections of shells are found, sometimes at a considerable height above the sea.

A remarkable deposit of large well-rounded quartz pebbles is found in the section exposed in the bank of the Shaulay-ar, 4 miles north of Nilambur. The pebbles reach a diameter of 6 or 8 inches, and seem to point to the former torrential character of this part of the river. They are found at the top of the bank 38 feet above the present bed of the river.

Recent Geological History of S. Malabar.

Before the laterite period Malabar stood 500 feet lower than at present and the sea washed the foot of the Ghâts. South Malabar was then a bay bounded on the north by the Camel's Hump and its outlying ranges, and on the south by the Cochin Hills. In the middle of the bay rose a chain of islands which are now Wallaiur or Wolaotúr Hill, Kondotti Hill, Urôtmala, Pandalur, Pranakód, and Anangamala. Pandalur and Pranakód Hills were probably united.

The land gradually rose, and at first a ledge of low-lying ground appeared round the central islands—Urôtmala, Pandalur, and Pranakód. This is now the highest part of the plateau.

The land rose higher and higher and the ledge became broader, till at last it joined the Ghâts near the peak of Kanjacombu, thus dividing the bay into two. This line of division is now the watershed between the Pandikád and Ponnáni Rivers.

At length the present level was reached, and instead of two bays were two valleys running from east to west, one north of the highest part of the plateau and the other south. In these two valleys flow the Beypore and Ponnáni Rivers. From the central highest land another river took its rise which is now the one flowing from Angádipuram to Malapuram and thence to Kadalhundi. At first all the streams east of the chain of gneiss hills had to run north or south to the Beypore or to the Ponnáni River, because they could not cut through the high land directly to the west. But at length a narrow gorge was cut between the hills of Urótmala and Pandalur through

the highest part of the plateau. One of the tributaries of the Beypore now found its way through this and joined the Kadalhundi River. This is the river that flows by Pandikád. The upper part of its course is at a lower level than the part of the plateau through which the gorge is cut.

As the land rose above the sea its surface became decomposed and at last lateritised. Valleys began to be formed in it long before the present level was reached. The watercourses being short and the slope slight, the valleys were broad and shallow, like those of the undulating region at the present time and like the upper part of the valleys of the gorge region. The depression in which New Malapuram stands is one of these old valleys. As the land rose, the fall of the rivers near their sources became greater, and hence they cut deeper and narrower channels at the bottom of the old valleys, and these channels are now the gorges. At the same time near the sea they cut the shallow valleys of the undulating region.

Since the land at the foot of the Ghâts rose above the sea later than the land round the central islands and the slope of the ground was less, the rivers there have never cut gorges but only shallow valleys.

It was on the plain of marine denudation as it gradually rose from the sea that the plateau laterite was formed; on the floors of the old river valleys, the terrace laterite; and on the floors of the new valleys, the valley laterite.

Economic Geology.

The laterite is by far the most useful of the formations found in Malabar. It is the great water-bearing stratum, and it supplies the most useful building materials.

The older laterite, from which all the clayey contents of the tubes have been washed out, is very barren and supports nothing but grass, oil-seed, and a few small trees. In 1855-56, during the extension of the Nilambur Teak plantations, several laterite hills were planted; but on these the teak completely failed. Fresher laterite, however,

which still contains the clay in its tubes, forms a valuable soil on which rice and other grains may be grown. Jungle grows very well on this soil while it is quite absent from the older laterite. The effect of this is that the summits of the hills capped by plateau laterite are covered with grass while the valleys are full of trees and undergrowth.

The use of laterite for building is too well known to require much remark. It is cut, when fresh, with a kind of axe, and hardens on exposure. None but the best varieties can resist a strong crushing force, and hence the failure of many bridges. It answers best when protected from the weather by an overhanging roof.

It is to the laterite that Malabar owes the perennial character of many of its streams. The rock being porous takes up a large quantity of water in the rainy season and serves as a reservoir during the hot weather.

There is a good deal of iron ore of very good quality in South Malabar; but even here, as in so many other parts of South India, the want of fuel is the great drawback to its manufacture. In Ernád Taluk the only place in which iron ore is at present made is in Porur amsam, but formerly it was made in Chembreri and Pandikád. The iron is of very good quality, but the workmen do not know how to make steel.

In Walluvanád Taluk mines are now worked in Nemini and Tachambára amsams; but some time ago there were mines in Mangada, Arakkaparamba, Melattur, and Vettatur.

The ore used is sometimes magnetite and sometimes hæmatite. In Mangada the old mines are in laterite and do not reach downward to the unlateritised part of the gneiss. In Arakkaparamba the ore is found in a quartz run and the upper surface of the ore is lateritised. In Nemini the ore is magnetite and occurs in crystals in the gneiss.

Among the alluvial deposits near the mouths of the rivers, and especially of the Beypore River, very good clays for bricks and tiles are found; and it is from these clays that the tile works of the Basel Mission at Calicut obtain their materials.

At Tirivulloy of the Atlas Sheet, about 3 miles west-south-west of Pálghát, bricks are made from the clay of the alluvial flats.

Alluvial washing for gold has been carried on in many of the rivers, principally at Nilambur and Manarkád. The gold of Nilambur has attracted a great deal of attention, and a short account of it will be found in the Manual of the Geology of India, Vol. III, pp. 180, *et seq.* There is no doubt that the sands of many of the rivers of South Malabar are highly auriferous, but the source of the gold must be looked for higher up, in the Wynaad, and in the ranges of the Silent and Attapádi Valleys.

APPENDIX.

Previous views on the Origin of Laterite.

An account of the geology of Malabar would hardly be complete without some reference to the views which have been held as to the origin of laterite. These views vary so much that I have preferred to discuss the origin of the *Malabar* laterite on the evidence found in Malabar alone, and to keep all reference to the laterite of other areas quite separate.

Much of the difference of opinion on the subject seems to have arisen from a want of agreement as to the exact meaning of the term.

Some writers appear inclined to restrict the term to rock formed in one particular way, and to exclude all laterite rocks that can be shown to have originated in any other manner. But the name, as originally proposed by Buchanan, appears to have been a purely lithological term, for he does not discuss the mode of origin. If any rock is, in hand specimens, undistinguishable from laterite, there is no reason why it should not be called laterite, whatever its mode of origin may have been.

Other writers, on the other hand, have used the term too laxly, and have called rocks laterite which should rather be called lateritic; but it must be admitted that it is hard to draw a line between a laterite containing pebbles and a conglomerate in which the pebbles are cemented together by laterite.

The number of writers who have discussed the origin of laterite is very great, and it would be useless to enumerate all; but the following account contains references to all the more important.

DR. BUCHANAN, who first gave the name of laterite, does not, in his first account of it, discuss the mode of origin of the rock; but in a paper on the minerals of the Rajmehal Hills he says that the laterites observed there must "be considered as a kind of breccia, as they contain ferruginous nodules in an argillaceous cement."[1] By the term breccia he evidently means conglomerate.

BENJAMIN BABINGTON,[2] who in 1821 described a journey from Tellicherry (in North Malabar) to Madras, says that the hornblende of the gneiss of the country decomposes into red oxide and the felspar into porcelain earth, thus forming laterite. Where exposed, the earth is washed away leaving the red oxide in the form of a porous ferruginous stone. This view, it will be seen, does not differ very much from that put forward in this report.

Another view was brought forward by DR. VOYSEY,[3] who in 1819 examined parts of the Nizam's Dominions. His observations on laterite were not published till after his death, and the fullest account of them will be found in the Journ. As. Soc., Beng., for 1844 and 1850; but a short notice was published in the same journal for 1833. At Bidar he found iron clay—this was his term for laterite—passing down "into wacké and thence into basalt."[4] He looks upon the iron clay as a "muddy eruption."[5]

[1] Gleanings in Science, III, 5.
[2] Geol. Trans., 1st series, V, 328.
[3] Journ. As. Soc., Beng., II, 298, 392; XIII, 853; XIX, 190, 269. The last two partly reprinted in Carter's Geol. Papers on Western India, 48-65.
[4] Geol. Papers on Western India, 61.
[5] *Loc. cit.*, 63.

This view appears to have been adopted by CALDER in his General Observations on the Geology of India. He calls the laterite "a contemporaneous rock associating with trap,"[1] but does not enter into the question of its origin.

DR. BENZA,[2] in his account of the Geology of the Nilgiris (1835, 1836), describes what he calls hæmatitic iron ore, which he says is often like laterite. But he does not consider it a true laterite. He describes the formation of lithomarge by the decomposition *in situ* of gneiss. He divides lateritic rocks into three groups, but his definitions of these groups are not very clear.

In a letter to COLE[3] he expresses the opinion that laterite has resulted from the decomposition of granitic and other crystalline rocks.

In 1836 COLE[4] gave a résumé of the earlier papers on the subject of laterite and described, from his own observations, the laterite of the Red Hills near Madras. From the presence of pebbles of sandstone and crystalline rocks in this laterite he concludes that it is a mechanical deposit. He does not consider the evidence in favour of Voysey's views satisfactory.

The next writer who enters into the question of the origin of laterite is DR. J. CLARK[5] (1838). He considers laterite and lithomarge to have been formed, both in the same way, by the decomposition *in situ* of gneiss; and he thinks it probable that lithomarge has been derived from a rock composed chiefly of hornblende and felspar, while laterite has been derived from rock containing more quartz. He divides lateritic rocks into three classes—(1) lithomargic, (2) quartzy, (3) detrital.

R. BAIRD SMITH[6] (1840-41) agrees with Clark's views and gives examples of this mode of formation of laterite.

The question of the origin of laterite is ably discussed by CAPT. NEWBOLD in his various papers on geology. The fullest account of his views is given in his Summary of the Geology of Southern India (Journ. Roy. As. Soc., VIII, IX, XII). He dismisses Voysey's theory that it is of igneous origin, on the ground that "no decided volcanic product has been discovered in laterite, no crater or other proof of such origin."[7] Occasionally, it fills pre-existing chinks in subjacent rocks, but it never enters as a vein injected from below. With regard to the theory that laterite is nothing more than granitic and other rocks weathered *in situ*, he contends that at the Red Hills near Madras, where the laterite rests on granite, it contains fragments of sandstone; and at other places beds of lignite, &c., occur interstratified with it. He examined many beds resting on trap containing chalcedonies, but did not detect in the upper or middle beds of the laterite any fragments of these chalcedonies. Laterite sometimes rests on limestone without containing any traceable lime.

He concludes that the rock is of aqueous and mechanical origin. On the Western Ghâts and on the West Coast, rocks containing much iron weather into ferruginous clays that resemble laterite, and when laterite is near, appear to pass into it. But Newbold does not consider these clays to be true laterite.

1 As. Res. XVIII, 4.
2 Mad. Journ. Lit. and Sci., IV, 241.
3 *Loc. cit.*, 108.
4 *Loc. cit.*, 100.
5 Mad. Journ. Lit. and Sci., VIII, 334.
6 Calc. Journ. Nat. Hist., I, 188.
7 Journ. Roy. As. Soc., VIII, 237.

O'RILEY[1] (1850) considers that laterite is formed by alteration of granitic rocks, but gives no evidence in favour of this view.

The view that laterite is formed by decomposition *in situ* of trap is strongly upheld by CAPT. WINGATE[2] (1852), whose observations were made in the Southern Konkan. His chief arguments are that laterite is always a superficial rock; that there are many cases of rocks of different kinds partly transformed into laterite; and that laterite presents distinctive peculiarities according to the nature of the subjacent rock. Laterite is almost limited to regions where there are heavy and long continued rains; but a similar rock is found in dry parts of the interior of the country in localities exposed to the action of running water. He describes a nodular trap with the outer concentric coats of the nodules converted into laterite and the harder centres unchanged.

In the Edinburgh New Philosophical Journal for 1852-53, there is a paper on the geology of Ceylon by E. F. KELAART.[3] He agrees with Clark in his classification of lateritic rocks, and states that the lithomargic variety is the most abundant in Ceylon. In Ceylon the laterite is never known to overlie or be interstratified with sedimentary beds as it is on the coast of Travancore. The stratification of the gneiss is often preserved in the laterite derived from it. He concludes that the laterite of Ceylon is formed by decomposition *in situ* of gneiss, and thinks it probable that detrital laterite is formed by disintegration and redeposition of the other variety.

The laterite of the Southern Konkan was re-examined by LIEUT. AYTOUN,[4] (1856), and he agrees with Captain Wingate that it is formed by decomposition of the trap. He says that there is a great deal of iron in the Konkan rocks. In his section of Vingorla headland he shows a hard detrital laterite forming a crust on the top of the thicker mass of softer laterite that has been formed by decomposition *in situ*.

Another observer on this part of the coast, F. BROUGHTON,[5] also comes to the conclusion that laterite is formed by the decomposition of trap. He says that there is always a layer of homogeneous and intensely-red clay between the trap and the laterite, and this layer is soft till exposed to the air, when it becomes hard and like laterite. He considers that a plentiful supply of rain is necessary for the formation of laterite. On one point mentioned in his paper, very few modern geologists will be found to agree with him. He believes that the elevation of the Ghâts took place after the formation of laterite. This was the view held by Elie de Beaumont; but it was successfully combated by Capt. Newbold.[6]

CARTER,[7] in his Summary of the Geology of India, adopts Voysey's view that laterite is a trappean rock, one of the latest outbursts of the Deccan trap. Depending on the observations of Stirling, he thinks that the laterite of Cuttack or Orissa has been intruded through the granite. In this he appears to have misunderstood Stirling who, though he mentions that the mixture of laterite and

[1] Journ. Ind. Archip., IV, 199.
[2] Trans. Bo. Geog. Soc., X, 287.
[3] Edin. New Phil. Journ. LIV, 28.
[4] Edin. New Phil. Journ. ser. 2, IV, 67.
[5] Journ. Bo. As. Soc., V, 639.
[6] Journ. Roy. As. Soc., XII, 80.
[7] Geol. Papers on Western India, 710.

granite is so intimate that in some specimens "it is not easy to pronounce which is the enclosing substance," yet says that "the granite at the place where the specimens were principally collected, appears to burst through an immense bed of the laterite, rising abruptly at a considerable angle,"......"in some specimens the two rocks are so mixed together as to form a sort of coarse breccia or rather conglomerate."[1] It is hardly necessary to remark that neither of the rocks is intrusive into the other and that the mixture is due to alluvial action.

Hislop[2] in his Geology of Nagpur, contends that as laterite occurs on sandstone as well as gneiss, it cannot have been formed by the decomposition of the gneiss.

In 1859 appeared Mr. Blanford's[3] account of the Laterite of Orissa. He, ike Lieutenant Aytoun, recognises two kinds of lateritic rocks, which he names laterite proper and lithomarge. Wherever they occur together the former always overlies the latter. Near hills it often contains pebbles, and it must therefore be detrital. The lithomarge, on the other hand, has evidently been formed by decomposition *in situ* of the gneiss. The quartzose layers of the gneiss extend into it. On exposure the lithomarge becomes hard like laterite. Mr. Blanford gives a series of analyses to show that there is a sudden decrease in the amount of iron present in passing down from the laterite to the lithomarge, and that the amount of iron in the lithomarge decreases with the depth till the water level is reached. He concludes that the iron in the lithomarge is derived from the laterite by the percolation of surface waters.

He thinks that the laterite was probably derived from the magnetic oxide in the gneiss. On decomposition the fine sand and clay are washed away and the coarser sand and magnetic oxide remain.

In the Trans. Bombay Geographical Society for 1860, Dr. Buist[4] discusses the laterite of Cochin and Quilon, which occurs with beds containing lignite and is clearly sedimentary. He considers that this laterite has been formed by the breaking up and redeposition of an older bed. He seems to agree with Aytoun and others that laterite was originally formed by decomposition *in situ* of various rocks.

Messrs. King and Foote[5] in their Geology of Salem and the adjoining districts recognise Mr. Blanford's two varieties of laterite, but the two occur quite separately. The lithomarge is formed by decomposition *in situ* of the gneiss, for the foliation is distinctly visible and the gradual transition from gneiss to lithomarge is clearly seen. This rock is the same as the pseudolaterite of the Nilgiris and Shevaroys. The laterite proper, on the other hand, is truly sedimentary. The underlying gneiss is almost always perfectly fresh; the gneissic rocks of the laterite area are mostly quartzose or felspatho-quartzose and do not contain much iron; and the laterite contains rounded fragments (almost pebbles) of quartz.

Up to this time laterite seems never to have been observed underlying any but the most recent deposits. But Mr. Blanford in 1869 describes sections in the

[1] As. Res., XV, 178.
[2] Journ. Bo. As. Soc., V, 58.
[3] Mem. G. S. I., I, 280.
[4] Trans. Bo. Geog. Soc., XV, p. xxii.
[5] Mem. G. S. I., IV, 260.

Narbada Valley, showing laterite underlying and interstratified with beds containing nummulites. At Wagulkhore[1] he found the following section (in ascending order):—

Laterite.
Yellow clay.
Pipe clay.
Ferruginous { Sands passing up into
Limestone with nummulites, gasteropods, &c.
Sandstone.
Laterite containing, in places, pebbles.

In one place the fossiliferous stratum is hardly distinguishable from laterite.

Other sections show laterite beneath a set of sedimentary beds and near Turkesur[2] a bed of laterite appears to lie between two beds of Nummulitic Limestone.

Somewhat similar cases are described by MR. WYNNE[3] in Kach. Laterite occurs regularly interbedded with the tertiary nummulitic beds, and there is also a subtertiary laterite. He figures an interesting case[4] (at Chaper) of a bed of laterite overlying a white unctuous rock and sending down stalactite-like processes into it, which are evidently due to infiltration.

MR. FOOTE,[5] in his Geology of Madras, shows clearly that the laterite of that part of the country is of sedimentary origin. It frequently contains pebbles. The highest laterite lies about 500 to 600 feet above the sea. Palæolithic implements were found *in situ* in the laterite, showing that the rock was in process of formation after the appearance of man upon the earth. Mr. Foote considers the laterite to have been formed in the sea, and suggests that the iron may be derived from magnetic iron sand. The greater the proportion of magnetic iron mixed with the other sand, the more ferruginous would be the laterite formed. At the present day large areas on the Coromandel Coast are black in colour, the colour being due to magnetic iron sand.

MR. THEOBALD,[6] in his Geology of Pegu, appears to consider the laterite of Pegu as due to the lateritisation, or, as he proposes to term it, the *laterosis*, of alluvial clays. He looks upon the laterite bordering the Poungloung range as the marginal deposit of a basin which has since been filled with alluvial clay.

In the South Mahratta country MR. FOOTE[7] separates the laterite of the Ghâts from that of the low country of the Konkan, and adopts Voysey's name—iron-clay—for the former. He considers the iron clay to have been formed by decomposition *in situ* of the trap rocks. There are numerous sections showing the passage of the basalt into a brownish earthy mass containing nuclei of the original rock. In the upper parts of the section the nuclei have disappeared and "a process of concretional solidification from the infiltration of surface waters holding iron in solution" has converted the rock into laterite. In only one case (*viz.*, at Chapoli, where quartz pebbles were found in the rock) was there any evidence of sediment-

[1] Mem. G. S. I., VI, 362.
[2] *Loc. cit.*, p. 367.
[3] Mem. G. S. I., IX, 1.
[4] *Loc. cit.*, p. 69.
[5] Mem. G. S. I., X, 27.
[6] Mem. G. S. I., X, 244.
[7] Mem. G. S. I., XII, 200.

ary origin. Mr. Foote infers from the conglomeratic nature of this Chapoli iron clay that it is either wholly or in part an altered intertrappean pebbly clay.

The iron clay occasionally overlaps the trap area and rests directly on other rocks. In the Gauli plateau it is found lying on gneiss. There is no external distinction between the iron clay found overlying trap and that found on gneiss. The passage downwards of the base of the clay into the gneiss is clearly seen.

The chief difficulty in Mr. Foote's view is, as he points out, that the agates and geodes so common in the trap-flows are never found in the summit bed of laterite. Mr. Foote supposes that the uppermost trap-flow, from which the summit bed was formed, may have been free from geodes. Such flows are not very uncommon in the Deccan traps, though the majority contain geodes.

The laterite of the Konkan[1] is believed by Mr. Foote to be sedimentary. It lies unconformably on the trap, and at Ratnagiri it overlies certain clays with lignite, resin, and plant remains. These clays are of Eocene age and clearly of sedimentary origin.

The laterite of the Rajmehal Hills is briefly described by MR. BALL.[2] There are at least two varieties, one occurring in patches on the metamorphic rocks west of the hills, the other commencing with the western scarp of the trappean rocks and stretching eastwards. This laterite gradually slopes downwards to the east and is continuous with the laterite of the plains. Many sections show an intimate connection between the laterite and the basalt, which suggests that the laterite may sometimes be merely altered basalt. But there is no proof of this.

In the Manual of the Geology of India,[3] (1879), MR. BLANFORD gives a condensed account of the laterite of India, which he divides into two groups—high level laterite (= iron clay of Voysey and Foote), and low level laterite. He discusses the mode of origin of the rock, and concludes that both forms are sedimentary. He suggests that the laterite may be the re-arranged and altered ashes, scoriæ, &c., which he considers were probably thrown out in great quantity at the close of the Deccan Trap period. The laterites of the Guzerat nummulitics were, in all probability, formed of volcanic detritus washed down into the sea, so that this mode of formation must at least be looked upon as possible.

MR. FOOTE,[4] in his Memoir on the East Coast from 15° N. L. to Masulipatam, describes the lateritic rocks of that area as consisting of sands, gravels, and conglomerates—clearly sedimentary.

In the Geological Magazine for July 1880 is a paper by MR. W. J. MCGEE[5] which compares the laterite of India with the ferriferous deposits of the Upper Mississippi Basin, and suggests that both may have been formed in the same way. The Mississippi deposits are insignificant compared with the Indian laterite, but the difference may be not in kind but in degree. "The Mississippi Valley ores are attributed to the agency of decomposing vegetable matter in liberating the iron from adjacent rocks and earth, and the subsequent combination of this iron with atmospheric oxygen." Mr. McGee suggests that the Indian laterite also may have been formed by the alteration *in situ* of the underlying rocks by atmospheric and

[1] *Loc. cit.*, p. 224.
[2] Mem. G. S. I., XIII, 222.
[3] Manual of the Geology of India, I, 334 ; II, 563.
[4] Mem., G. S. I., XVI, 85.
[5] Geol. Mag., New Series, Dec. II, Vol. VII (1880), 310.

chemical agencies, modified by the action of decomposing vegetation. The accumulation of laterite in any region would then depend on (1) the solubility of the basal rock, (2) the proportion of contained iron, (3) the fertility of the soil formed by its disintegration, and (4) the climate of the region.

A somewhat similar view is upheld by MR. MALLET,[1] who compares the Indian laterite with the ferruginous beds associated with the basaltic rocks of N. E. Ireland. The differences between the two are considerable. The Irish rocks are nearly always compact, and the mottled character so commonly present in laterite is not found in them. They consist partly of magnetic oxide. But Mr. Mallet does not look upon these differences as essential. The Irish beds, as suggested by D. Forbes, have probably been formed in much the same way as the bog iron ore of Sweden, and Mr. Mallet supposes that the Indian laterite was also formed in the same way. He agrees with Mr. McGee in attributing the separation of the iron to the action of decomposing vegetation, but believes that the laterite was formed in lakes and not by decomposition *in situ*.

MR. BALL,[2] in his account of Manbhum and Singhbhum, holds that as the laterite accommodates itself to the contour of the ground, it cannot have been formed in lakes. He is inclined to agree with the view that it is a modified volcanic ash, the iron having been concentrated by segregation.

DR. KING,[3] in his Geology of Travancore, states that there certainly are cases in which the laterite has been formed by decomposition *in situ* of gneiss, for it is frequently seen to pass gradually downwards into the gneiss. Detrital laterite occurs near the coast.

The last paper to which it will be necessary to refer is that of MR. BOSE[4] on the Manganiferous Iron and Manganese ores of Jabalpur. He divides the lateritic rocks into three groups :—(1) Lateritised Bijawar rocks. The gradual change of the Bijawar rocks into laterite is well seen near Gosalpur. (2) Lateritic rocks associated with the Gosalpur quartzites. The lateritic rocks alternate with the quartzites. In several pits large blocks of quartzite were found *in situ* surrounded on all sides by laterite, and there are other evidences that *some* of this laterite is formed by alteration of the quartzites. (3) Lateritic alluvium.

From this summary it will be seen that the view taken by an author has generally depended more or less on the area in which his observations were made. Thus most observers on the East Coast have come to the conclusion that laterite is of sedimentary origin. Those also who saw the laterite of Quilon and the *coast* of Travancore, look upon it as detrital. In this they are confirmed by Dr. King,[5] who, however, believes that the rock further inland has been formed by decomposition *in situ*. Further up the West Coast, in the Konkan, most writers are agreed that much of the laterite has been formed by decomposition *in situ*, though at Ratnagiri, where it overlies plant beds, it must be detrital.

With regard to the laterite of the Deccan and Western Ghâts, opinions are more divided. Mr. Foote's views have already been mentioned, and his evidence is very strong. The theory proposed by Dr. Blanford that laterite is re-assorted volcanic detritus, ash, &c., does not account for the fact that laterite is quite as

[1] Rec. G. S. I., XIV. 139.
[2] Mem. G. S. I., XVIII, 122.
[3] Rec. G. S. I., XV, 96.
[4] Rec., G. S. I., XXII, 220.
[5] Rec., G. S. I., XV, 97.

well developed in Travancore and Ceylon as it is in the midst of the Deccan Trap area. Moreover, if there were so many cones of ash, &c., as would be needed to furnish all the materials for the laterite, more traces of volcanic centres than are now known, would surely have been found. It is usually supposed now that the Deccan Trap flows arose from fissures, probably without the explosive action necessary to produce pumice, ashes, and tuff. The argument that some (the Guzerat) laterite has been formed in this way can equally well be used in favour of the "lateritisation" theory, for it is certain that *some* laterite has been formed by decomposition *in situ* of older rocks.

That laterite is very often detrital is undoubtedly true; and it is also as true that some has been formed by decomposition *in situ*. The occurrence of well-rounded pebbles in the former case, and of the vertical quartz laminæ of the gneiss in the latter, is quite sufficient to show this; and to give further proofs would be simply to repeat what has already been written either in the body of this report or in this Appendix.

The greatest development of solid rock laterite is certainly to be found near the coasts, and more particularly the West Coast; and any theory that ignores this cannot be considered satisfactory. From the extent of laterite on the summits of the Western Ghâts in the Mahratta country, it is clear that a high elevation does not affect the formation of laterite and that laterite cannot, in all cases at least, have been formed under the sea. The only characteristics that the Ghâts and the low country of the West Coast seem to have in common, are a damp climate and a luxuriant vegetation; and in these both differ from the greater part of the interior of the Peninsula. It is not unnatural to assume, therefore, that these are the chief agents in the formation of laterite.

Hence we are led to Mr. McGee's hypothesis that decomposing vegetation aided by a hot damp climate has caused the concentration of the iron in the soil. The remainder of the decomposed part of the rock has been washed away by the heavy rains. The laterite is too uniformly spread to have been formed in lakes as Mr. Mallet's theory requires.

Laterite was originally formed *in situ;* but the heavy rains must have scattered a considerable quantity of the iron nodules as they were forming, and therefore it is rather rare to find a bed of laterite that has been *wholly* formed by decomposition *in situ;* though beds, the greater part of which has been so formed, are very common. When once a bed of laterite has been completed, it is always liable to be broken up and re-deposited elsewhere. Re-consolidation and concretionary action will soon reconvert it into a typical laterite.

It is probable that decomposing vegetation is not *necessary* for the formation of laterite, though it hastens the process. In some places where vegetation is not very abundant, laterite appears to be forming at the present day.

The absence of laterite in the Himalayas[1] may be due partly to the want of continuous heat and partly to the nature of the rocks, which are probably not so ferruginous as the traps and gneisses of the Peninsula.

[1] A pisolitic ferruginous clay resembling laterite occurs in the Subáthu group in the Jamu area and also in the Salt Range (Manual of the Geology of India, II, p. 563). A ferruginous bed resembling laterite is also found on the top of the nummulitics near Jesalmir (Oldham, Rec. G. S. I., XIX, 159), but laterite is extremely rare in India outside of the Peninsula.

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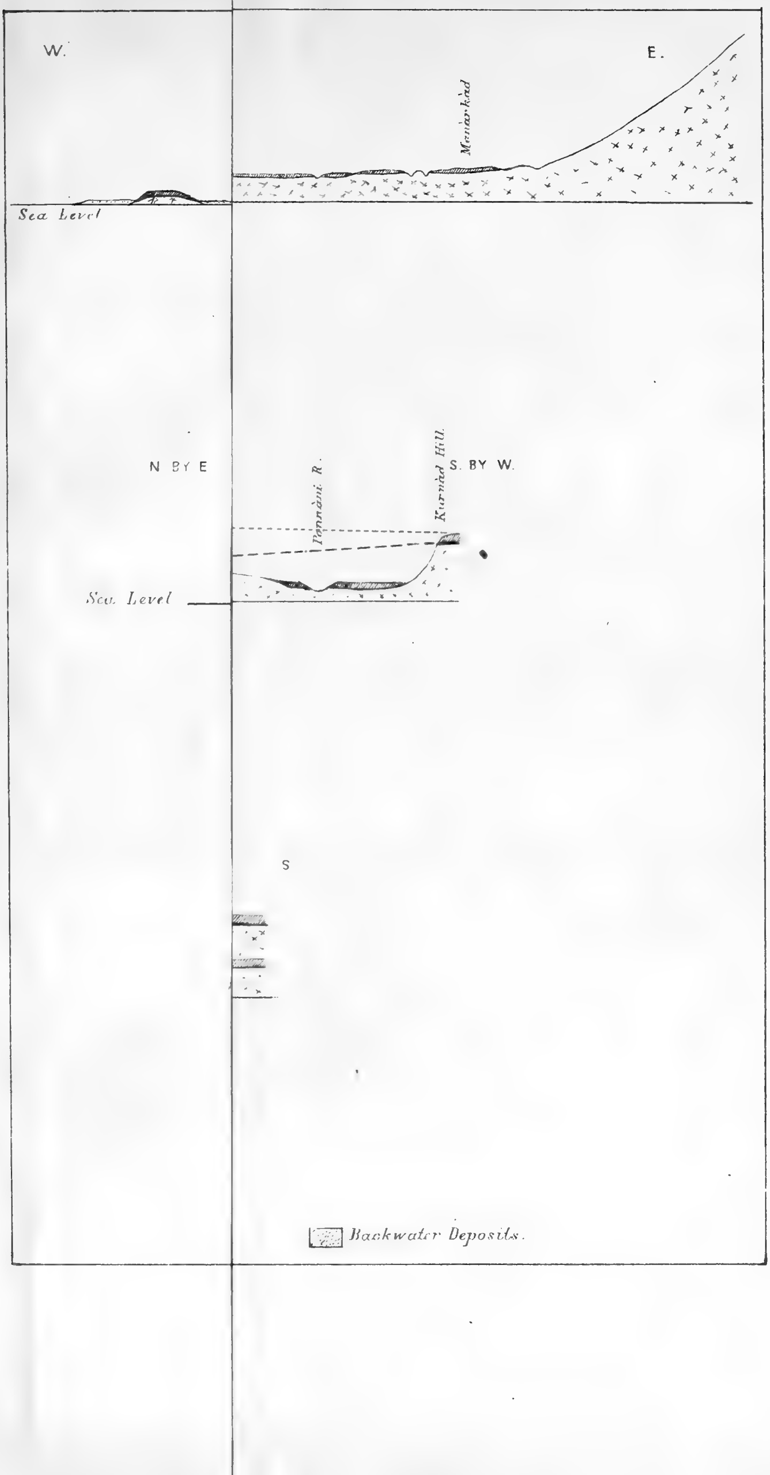
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Kurnad Hill
S. BY W.
Sea Level
S
Backwater Deposits.

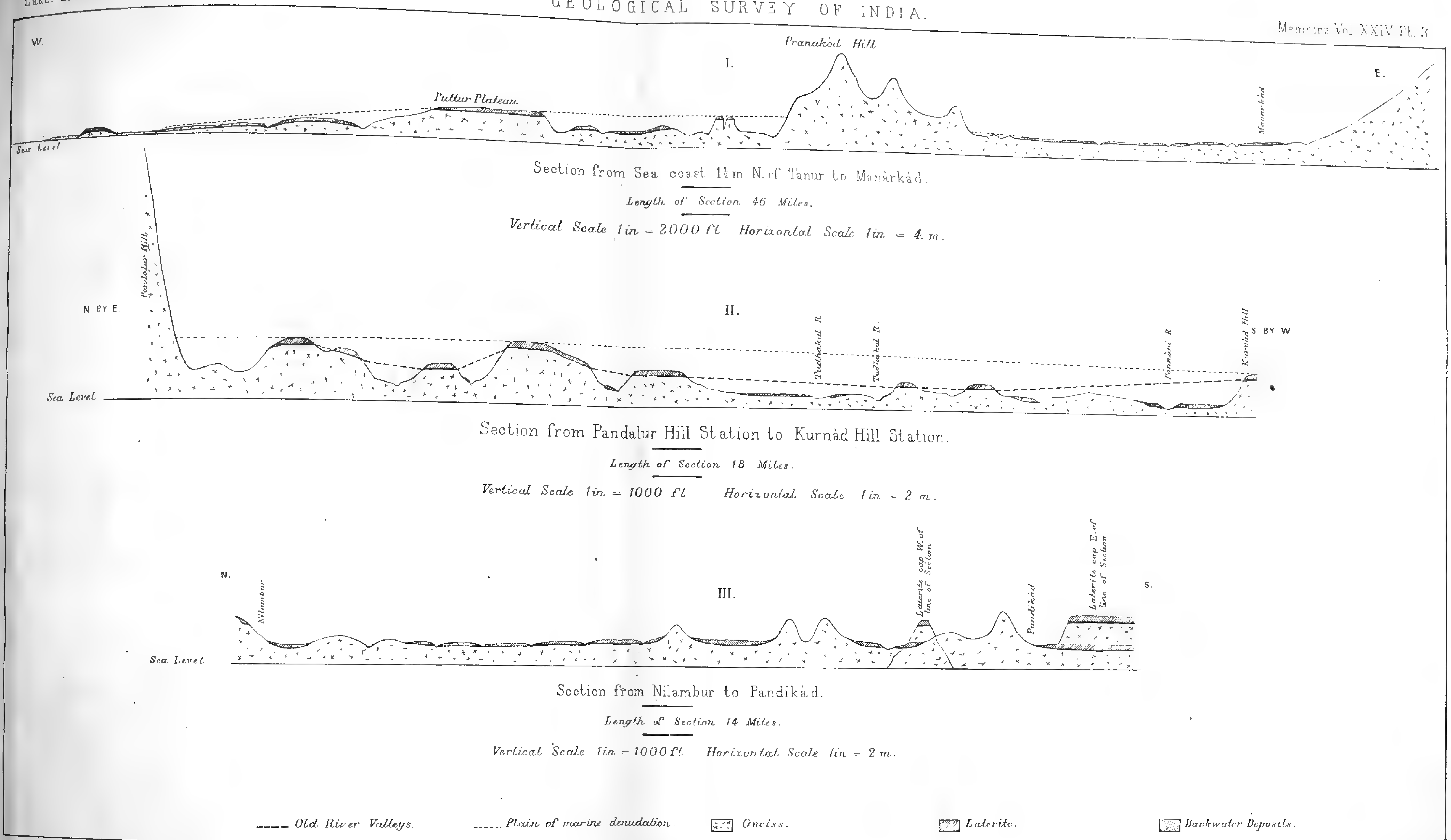
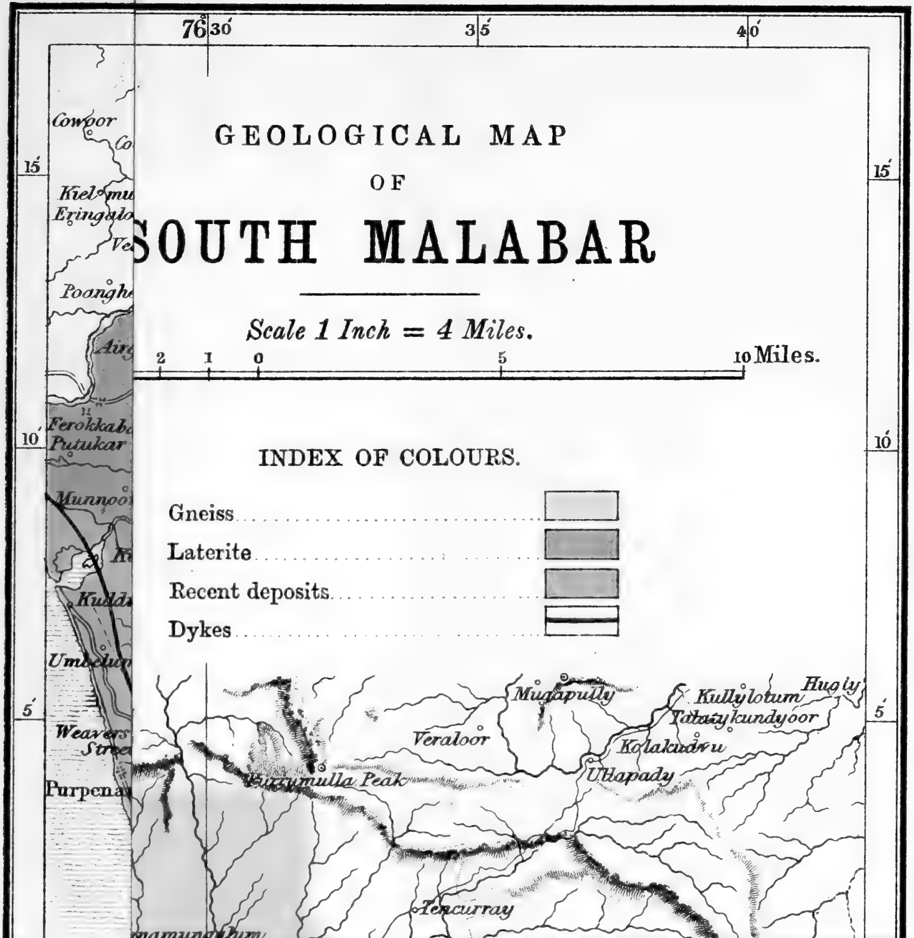
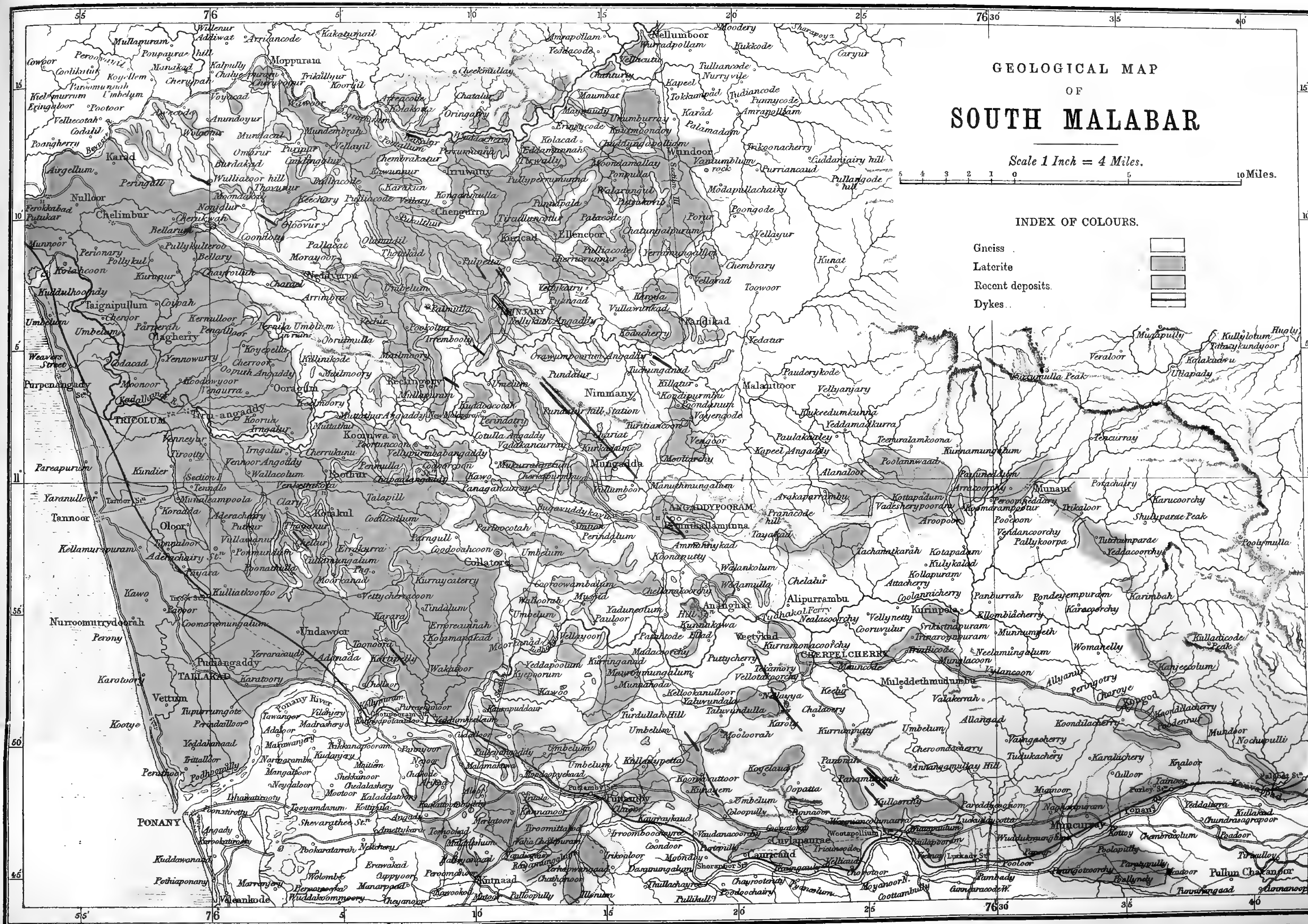

W.
Pranakòd Hill
I.
Puttur Plateau
E.
Manarkad
Sea level
Section from Sea coast 1½ m N. of Tanur to Manàrkàd.
Length of Section 46 Miles.
Vertical Scale 1 in = 2000 ft Horizontal Scale 1 in = 4. m.
Pandalur Hill
N BY E.
II.
Tudikakal R.
Tudhikal R.
Ponnani R.
Kurnàd Hill
S BY W
Sea Level
Section from Pandalur Hill Station to Kurnàd Hill Station.
Length of Section 18 Miles.
Vertical Scale 1 in = 1000 ft Horizontal Scale 1 in = 2 m.
N.
Nilambur
III.
Laterite cap W. of line of Section
Pandikàd
Laterite cap E. of line of Section
S.
Sea Level
Section from Nilambur to Pandikàd.
Length of Section 14 Miles.
Vertical Scale 1 in = 1000 ft. Horizontal Scale 1 in = 2 m.
Old River Valleys.
Plain of marine denudation.
Gneiss.
Laterite.
Backwater Deposits.

Plate. VIII.


GEOLOGICAL MAP
OF
SOUTH MALABAR
Scale 1 Inch = 4 Miles.
2 1 0 5 10 Miles.
INDEX OF COLOURS.
Gneiss
Laterite
Recent deposits
Dykes
76°30′
35′
40′
15′
10′
5′
Cowgor
Kiel mu
Eringalo
Poanghe
Ferokkaba
Putukar
Munnoo
Umbelum
Weavers Stre
Purpena
Muqapully
Kullylotum
Hugly
Talaiy kundyoor
Veraloor
Kolakudvu
Ullapady
Tencurray
namungalum



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Litho., S. I. O., Calcutta.

Taken from Sheet 61 of the Atlas of India